Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

March 16th, 2022

(data current to March 12th – March 15th)
Biocomplexity Institute Technical report: TR 2022-018

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biocomplexity.virginia.edu

About Us

- Biocomplexity Institute at the University of Virginia
  - Using big data and simulations to understand massively interactive systems and solve societal problems
- Over 20 years of crafting and analyzing infectious disease models
  - Pandemic response for Influenza, Ebola, Zika, and others

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Overview

- **Goal**: Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
  - Calibrate explanatory mechanistic model to observed cases
  - Project based on scenarios for next 4 months
  - Consider a range of possible mitigation effects in "what-if" scenarios
- **Outcomes:**
  - Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
  - Geographic spread over time, case counts, healthcare burdens

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

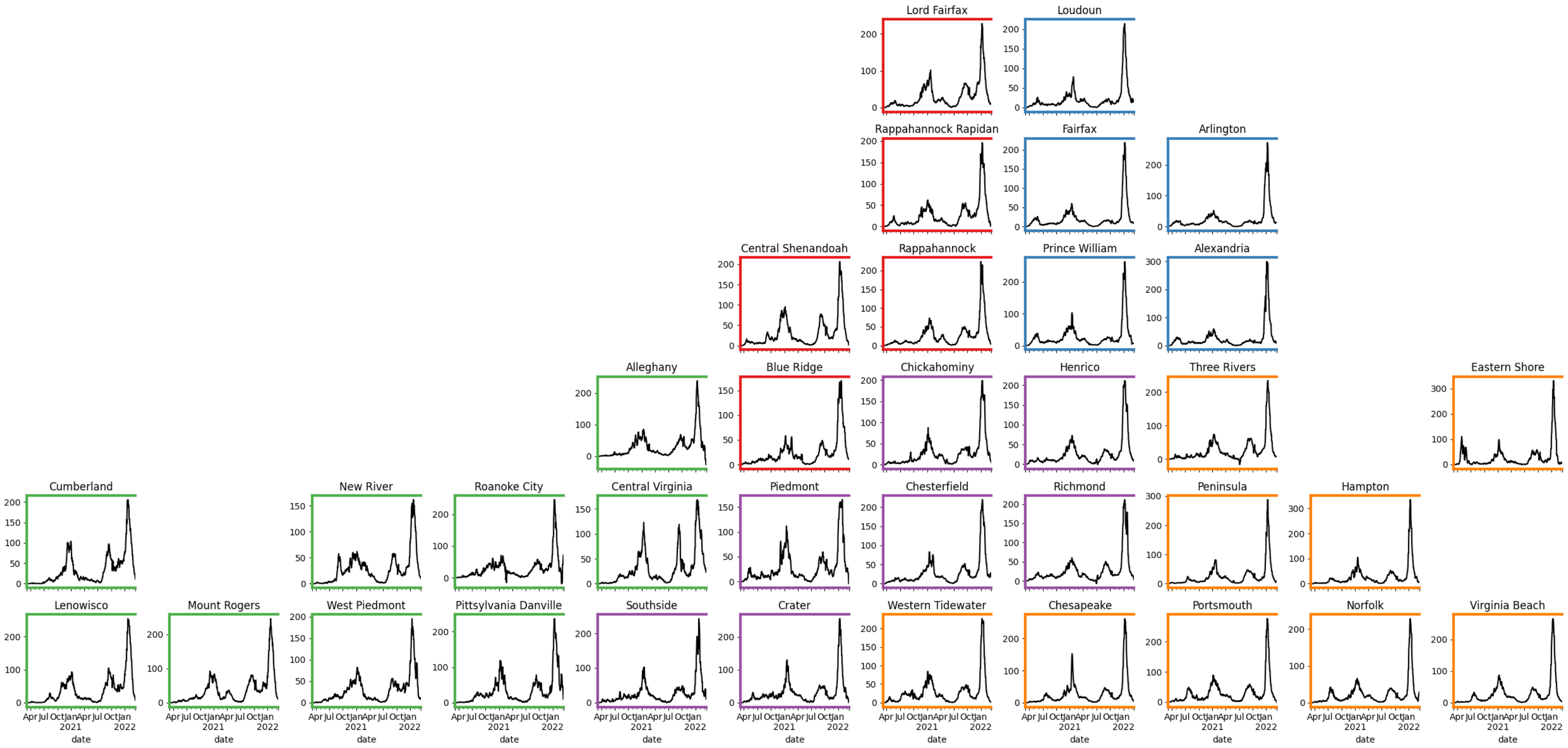
- **Case rates and hospitalizations continue to decline, though rate of decline is slowing**
- VA 7-day mean daily case rate slowly decreased to 11/100K from 14/100K
  - US continues declines to 10/100K (from 13/100K)
- BA.2 subvariant of Omicron has resumed steady growth, though slower than previously observed in European countries many of which now have rebounding case rates
- Projections anticipate continued declines:
  - Future levels and resilience to new variants and reduced infection control measures depend on the strength of immunity gained through infection with Omicron and its durability against waning
- Model updates:
  - Further calibration of model parameters to match recent data on population immunity post-Omicron wave continue and will provide better long-term estimates of future disease dynamics

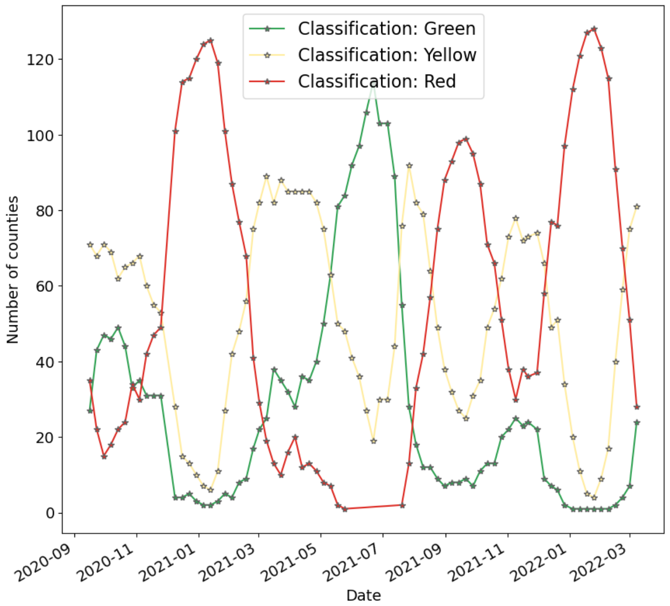
The situation continues to change. Models continue to be updated regularly.

Situation Assessment

Case Rates (per 100k) and Test Positivity

Data source: https://data.cms.gov/covid-19/covid-19-nursing-home-data





County level RT-PCR test positivity

Green: <5.0% (or <20 tests in past 14 days)

Yellow: 5.0%-10.0% (or <500 tests and <2000 tests/100k and >10% positivity over 14 days)

Red: >10.0% (and not "Green" or "Yellow")

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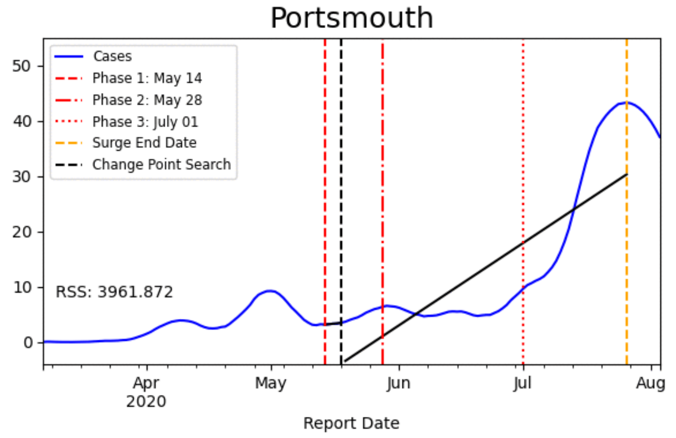
District Trajectories

Goal: Define epochs of a Health District's COVID-19 incidence to characterize the current trajectory

Method: Find recent peak and use hockey stick fit to find inflection point afterwards, then use this period's slope to define the trajectory

Hockey stick fit



Trajectory	Description	Weekly Case Rate (per 100K) bounds	# Districts (prev week)
Declining	Sustained decreases following a recent peak	below -0.9	35 (35)
Plateau	Steady level with minimal trend up or down	above -0.9 and below 0.5	0 (0)
Slow Growth	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5	0 (0)
In Surge	Currently experiencing sustained rapid and significant growth	2.5 or greater	0 (0)

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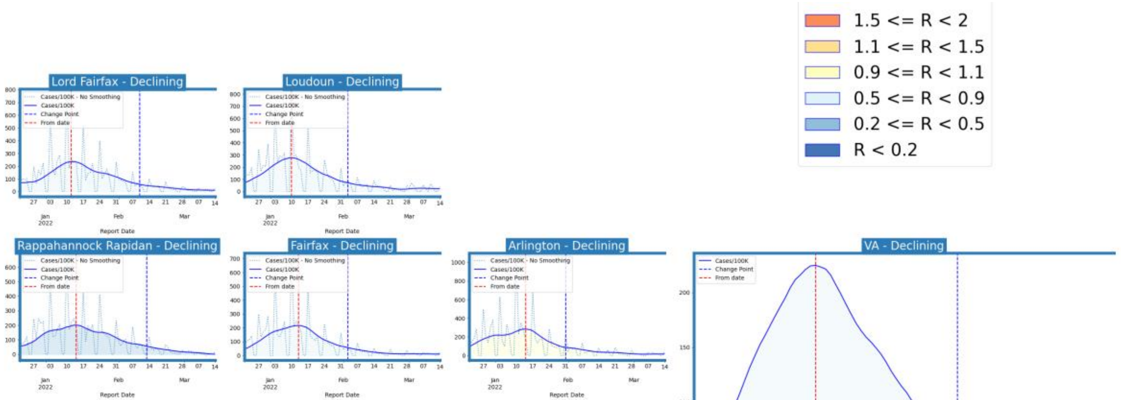
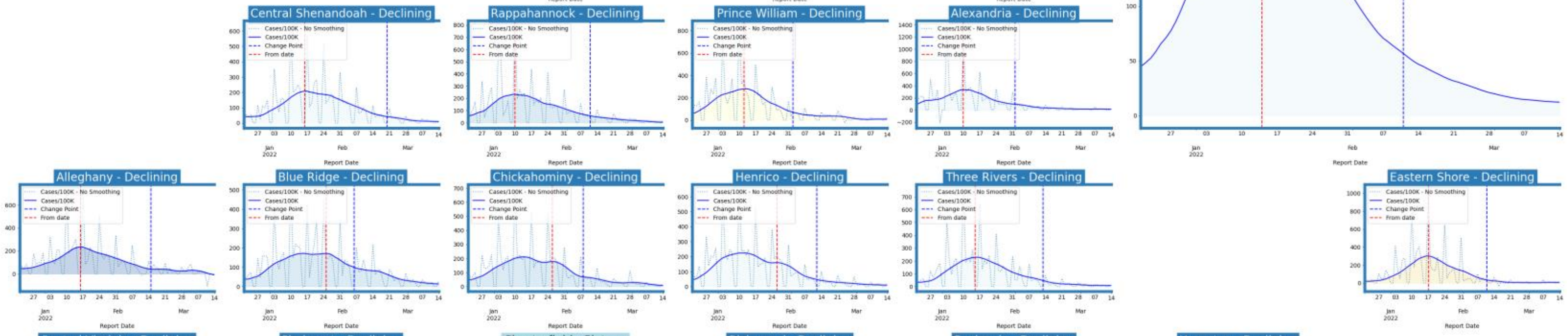
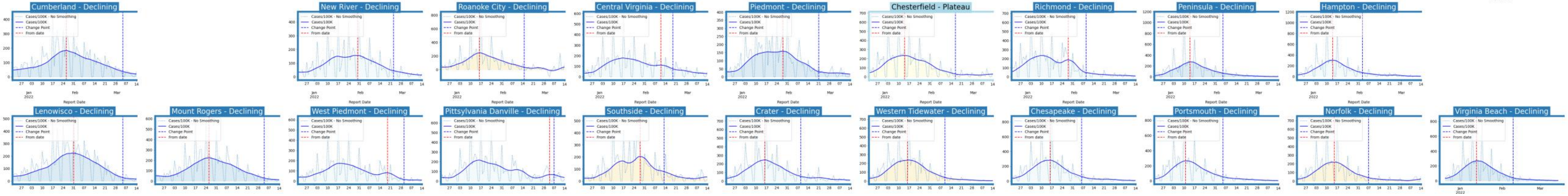
District Trajectories – last 10 weeks

Status	# Districts (prev week)
Declining	34 (35)
Plateau	1 (0)
Slow Growth	0 (0)
In Surge	0 (0)

Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive number







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CDC's new COVID-19 Community Levels

What Prevention Steps Should You Take Based on Your COVID-19 Community Level?

Low	Medium	High
• Stay up to date with COVID-19 vaccines • Get tested if you have symptoms	• If you are at high risk for severe illness, talk to your healthcare provider about whether you need to wear a mask and take other precautions • Stay up to date with COVID-19 vaccines • Get tested if you have symptoms	• Wear a mask indoors in public • Stay up to date with COVID-19 vaccines • Get tested if you have symptoms • Additional precautions may be needed for people at high risk for severe illness

People may choose to mask at any time. People with symptoms, a positive test, or exposure to someone with COVID-19 should wear a mask.

COVID-19 Community Levels – Use the Highest Level that Applies to Your Community

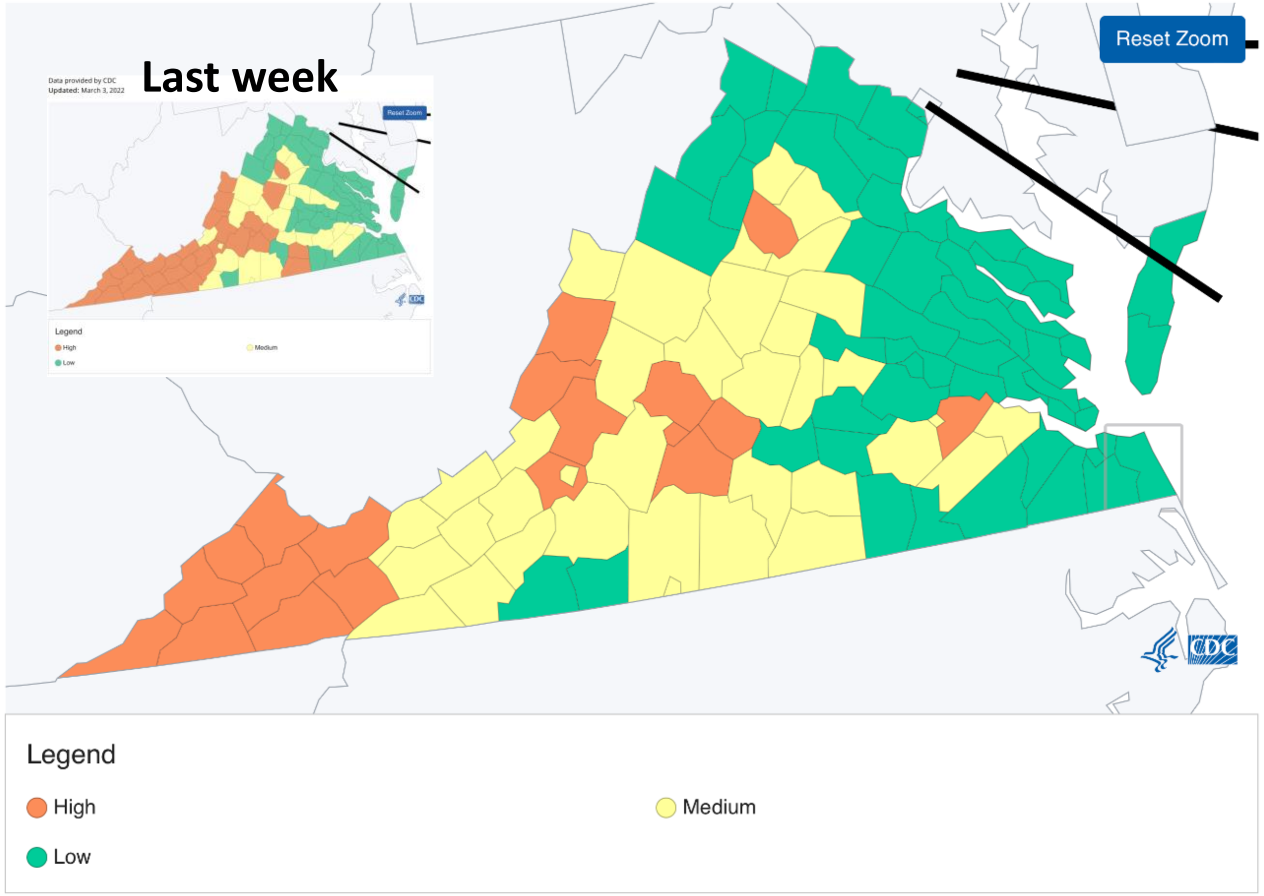
New COVID-19 Cases Per 100,000 people in the past 7 days	Indicators	Low	Medium	High
Fewer than 200	New COVID-19 admissions per 100,000 population (7-day total)	<10.0	10.0-19.9	≥20.0
	Percent of staffed inpatient beds occupied by COVID-19 patients (7-day average)	<10.0%	10.0-14.9%	≥15.0%
200 or more	New COVID-19 admissions per 100,000 population (7-day total)	NA	<10.0	≥10.0
	Percent of staffed inpatient beds occupied by COVID-19 patients (7-day average)	NA	<10.0%	≥10.0%

The COVID-19 community level is determined by the higher of the new admissions and inpatient beds metrics, based on the current level of new cases per 100,000 population in the past 7 days

U.S. COVID-19 Community Levels by County Map

Maps, charts, and data provided by CDC, updates every Thursday by 8 pm ET

Updated: March 10, 2022



CDC Data Tracker Portal

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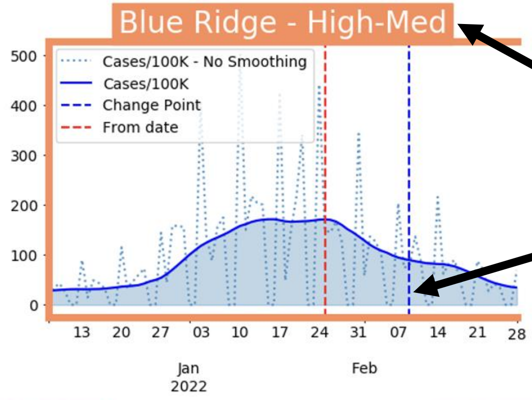
District Trajectories with Community Levels

Community Level
(Title Color)
- High
- High-Med
- Med-High
- Medium
- Med-Low
- Low-Med
- Low

Curve shows smoothed case rate (per 100K)
CDC's new [Community Level](#) aggregated to district level in label & chart box color
Case Rate curve colored by Trajectory

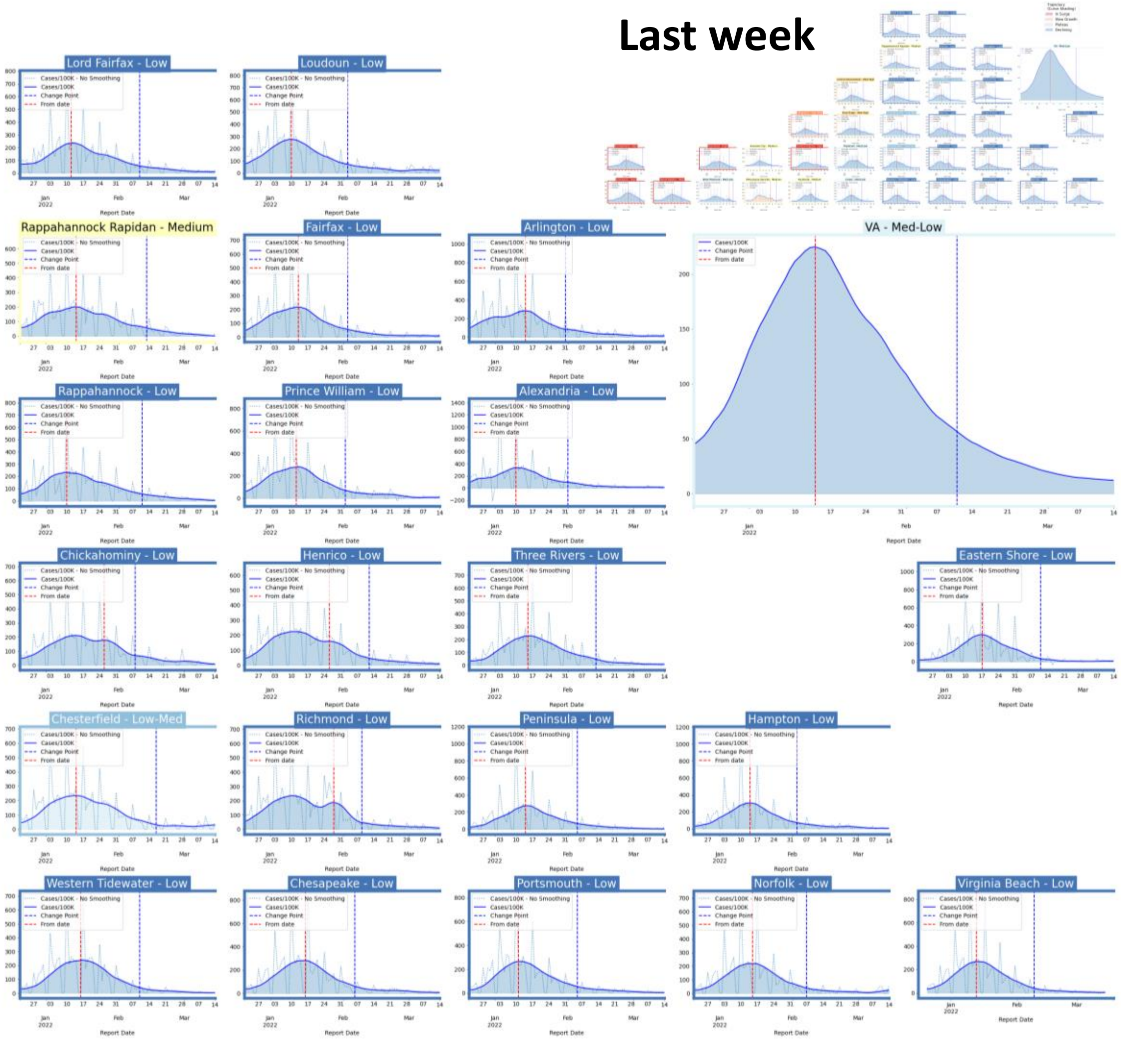
Trajectory
(Curve Shading)
- In Surge
- Slow Growth
- Plateau
- Declining

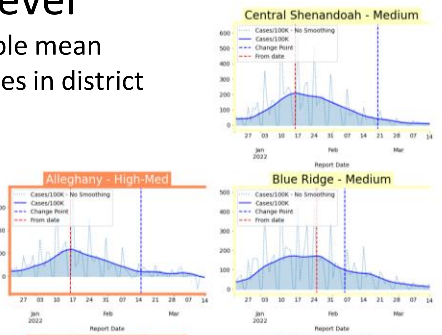


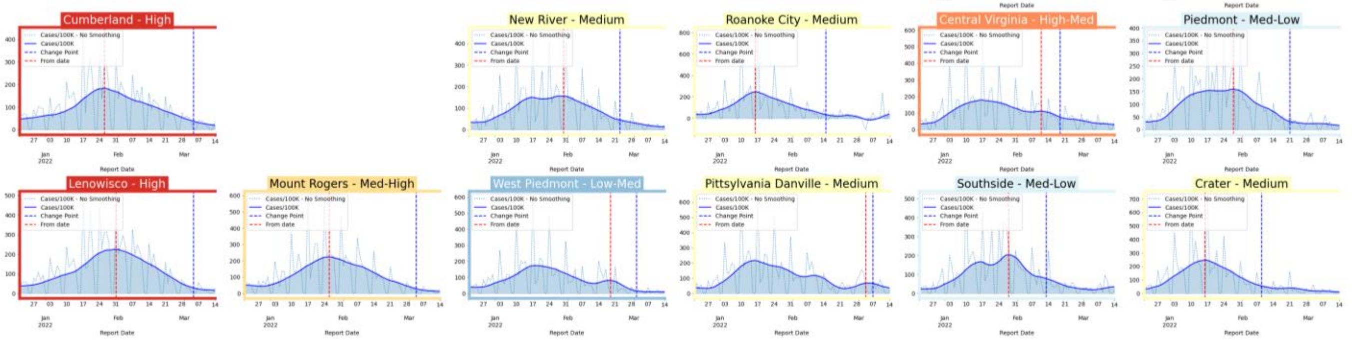
District's Aggregate Community Level
Aggregate level a simple mean of all levels for counties in district

Case rate Trajectory

Last week







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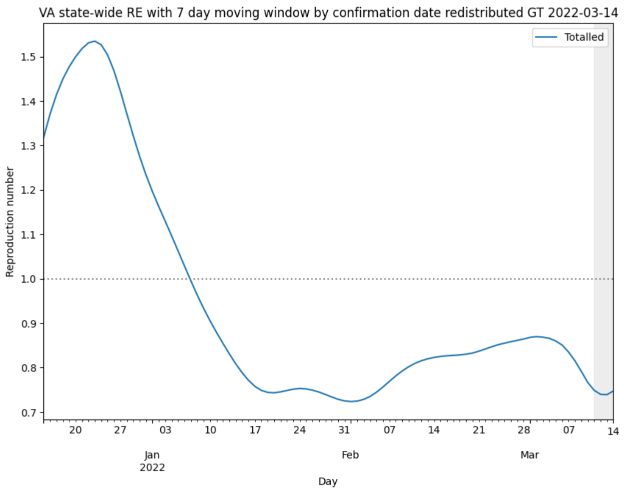
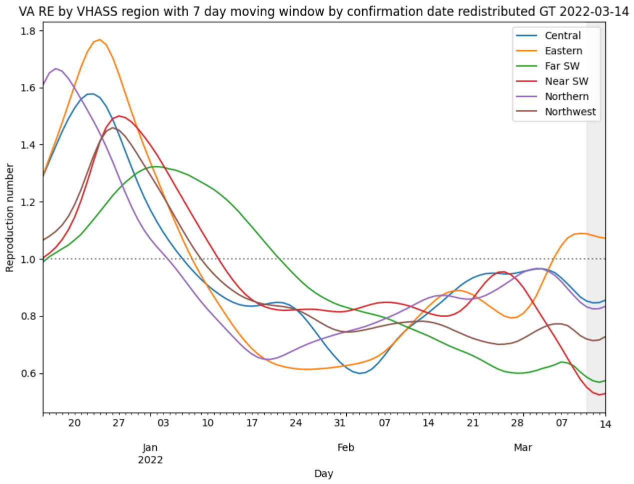
Estimating Daily Reproductive Number – Redistributed gap

March 14th Estimates

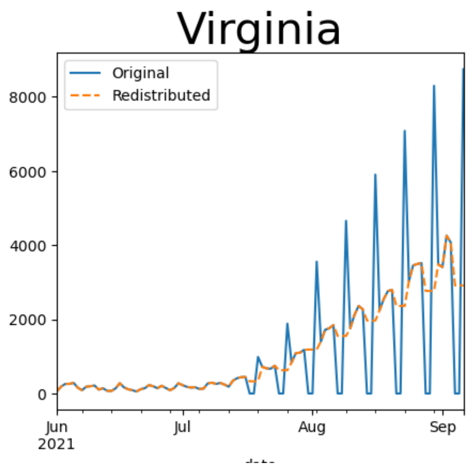
Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	0.748	0.008
Central	0.853	-0.028
Eastern	1.078	0.632
Far SW	0.573	0.122
Near SW	0.524	-0.248
Northern	0.838	-0.082
Northwest	0.728	0.080





Skipping Weekend Reports & holidays biases estimates

Redistributed "big" report day to fill in gaps, and then estimate R from "smoothed" time series



Methodology

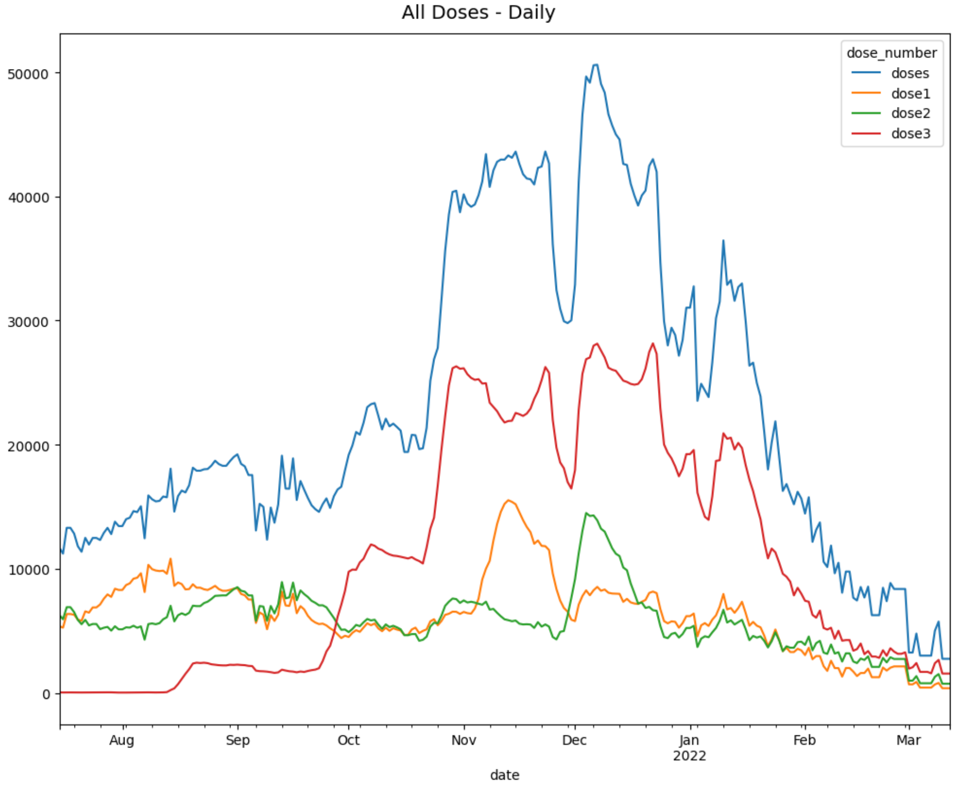
- Wallinga-Teunis method (EpiEstim[1]) for cases by **confirmation date**
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

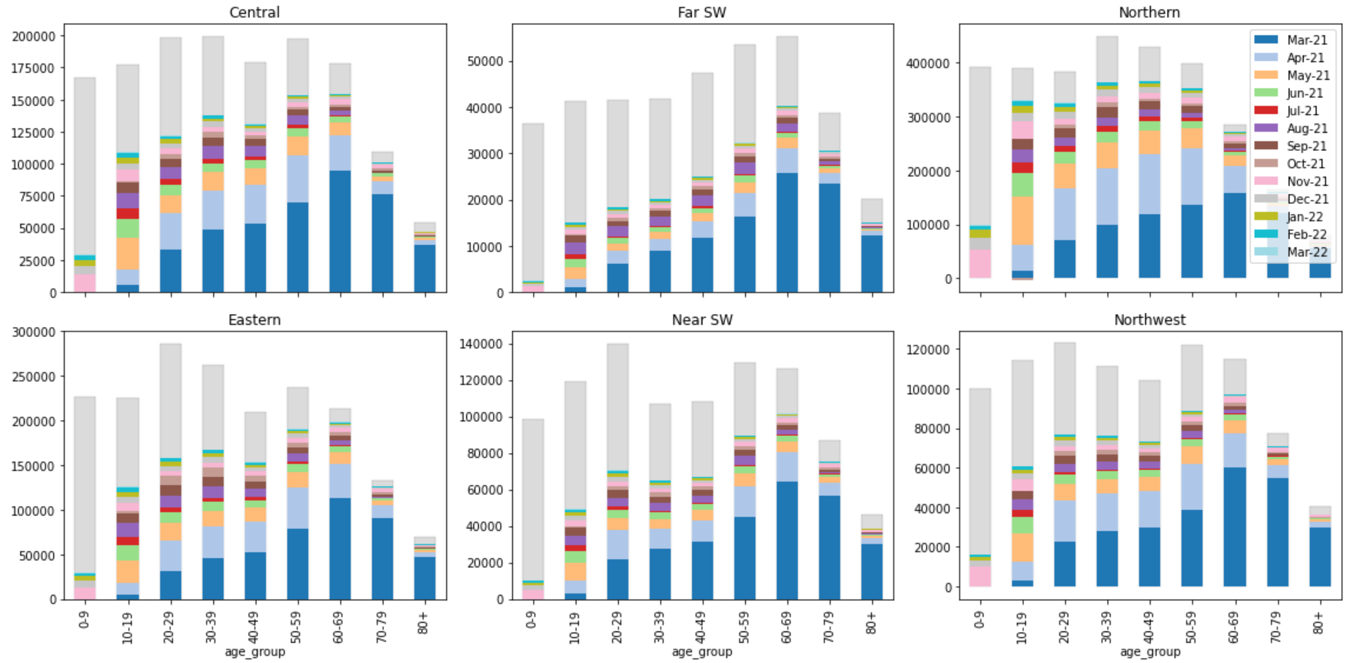
1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

Vaccination Administration in Virginia

Vaccine Doses administered:

- Doses administered rates continue to slow into a low-level plateau
- Considerable reduction in vaccination rate experienced since mid-January
- Third dose administration remains highest





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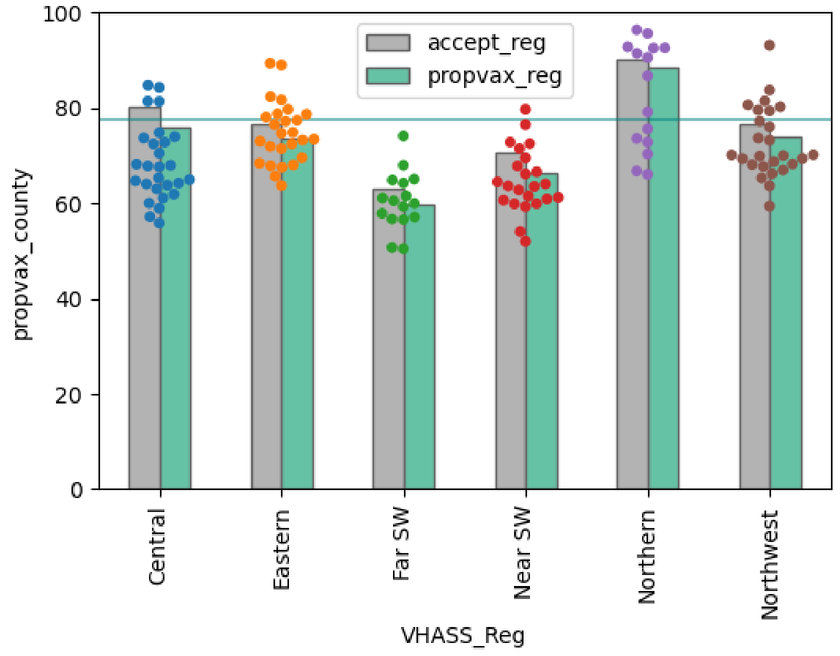
Vaccination Acceptance by Region

Corrections to surveys:

- Facebook administered survey is timely and broad, but biased by who accesses Facebook and answers the survey
- Correction approach:
  - Calculate an over-reporting fraction based on reported vaccinations compared to VDH administration data
  - Cross-validate coarse corrections against HPS survey at the state level and corrected in same manner

Region	COVIDcast accepting corrected	VDH proportion pop vaccinated
Central	79%	76%
Eastern	76%	73%
Far SW	62%	60%
Near SW	69%	66%
Northern	91%	88%
Northwest	76%	74%
Virginia	**80%**	**77%**



Grey Bar: Survey measured and corrected acceptance
Green Bar: Proportion of eligible population administered a vaccine
Dots: Proportion administered at least one dose for each county

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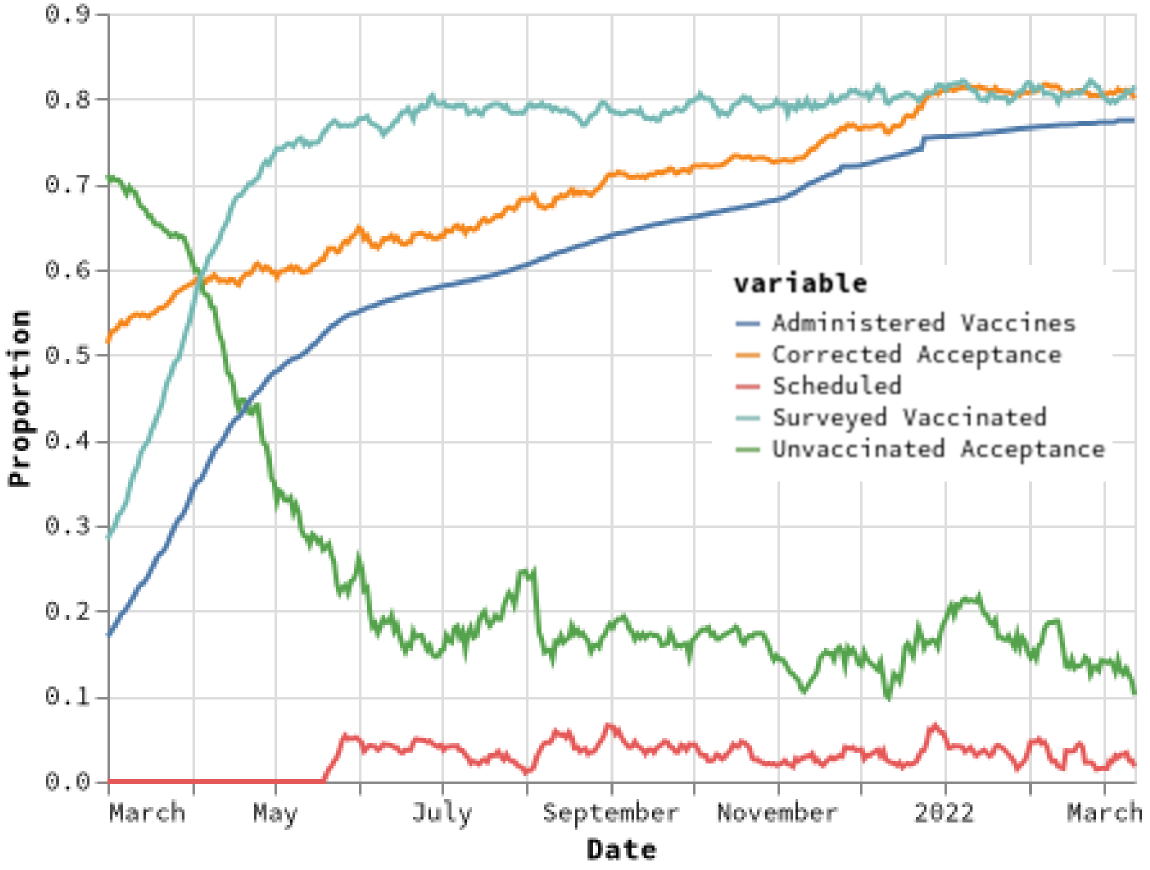
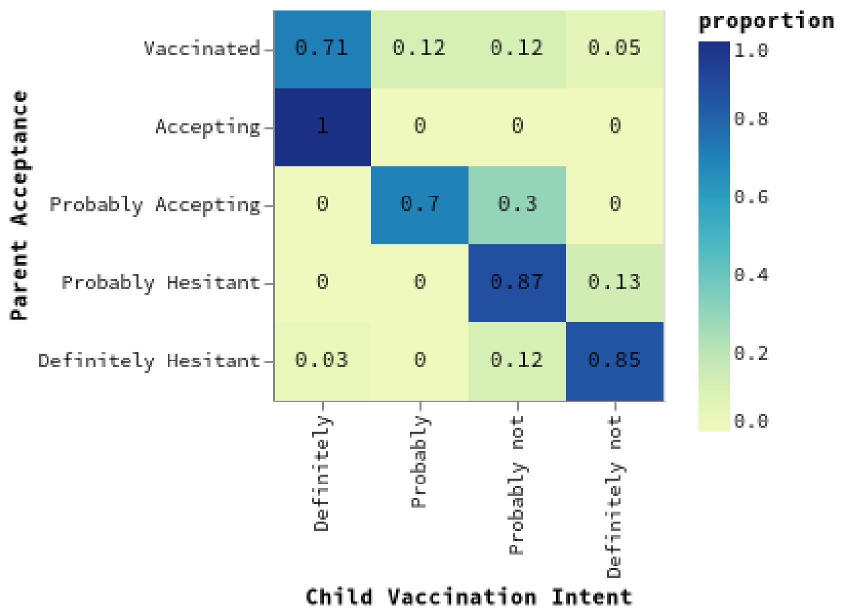
Vaccine Acceptance Components over Time



Vaccine Acceptance adjusted to include scheduled appointments

- Steady rise in acceptance over the past couple months
- Unvaccinated Acceptance shows ~12% of those who are unvaccinated are definitely or probably willing to be vaccinated

Intent to Vaccinate Children Based on Parent's Acceptance Level

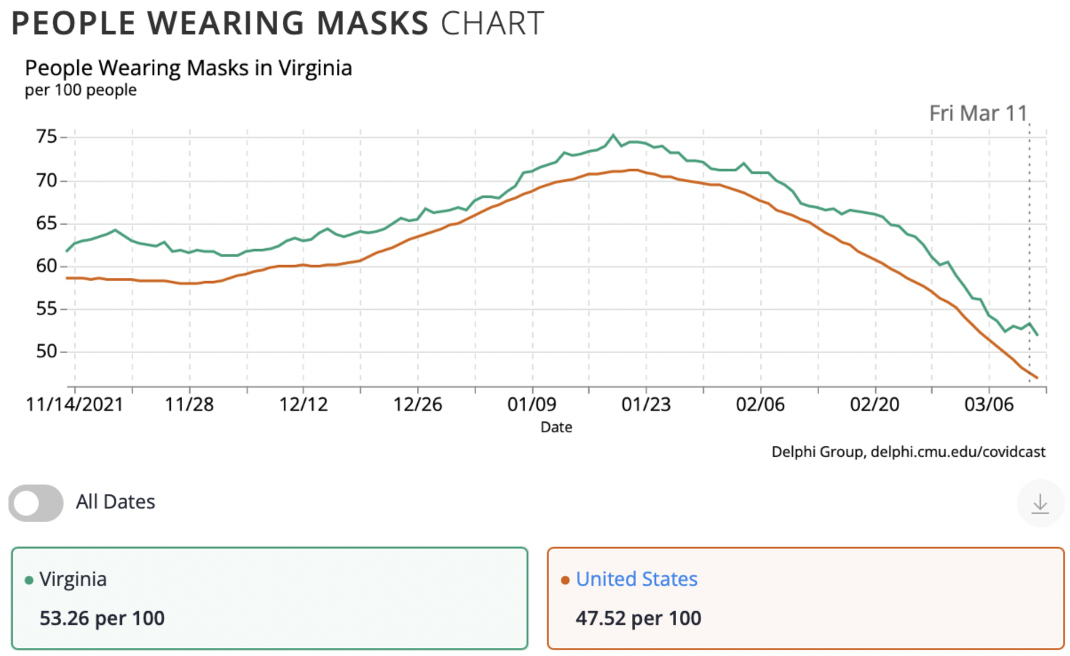


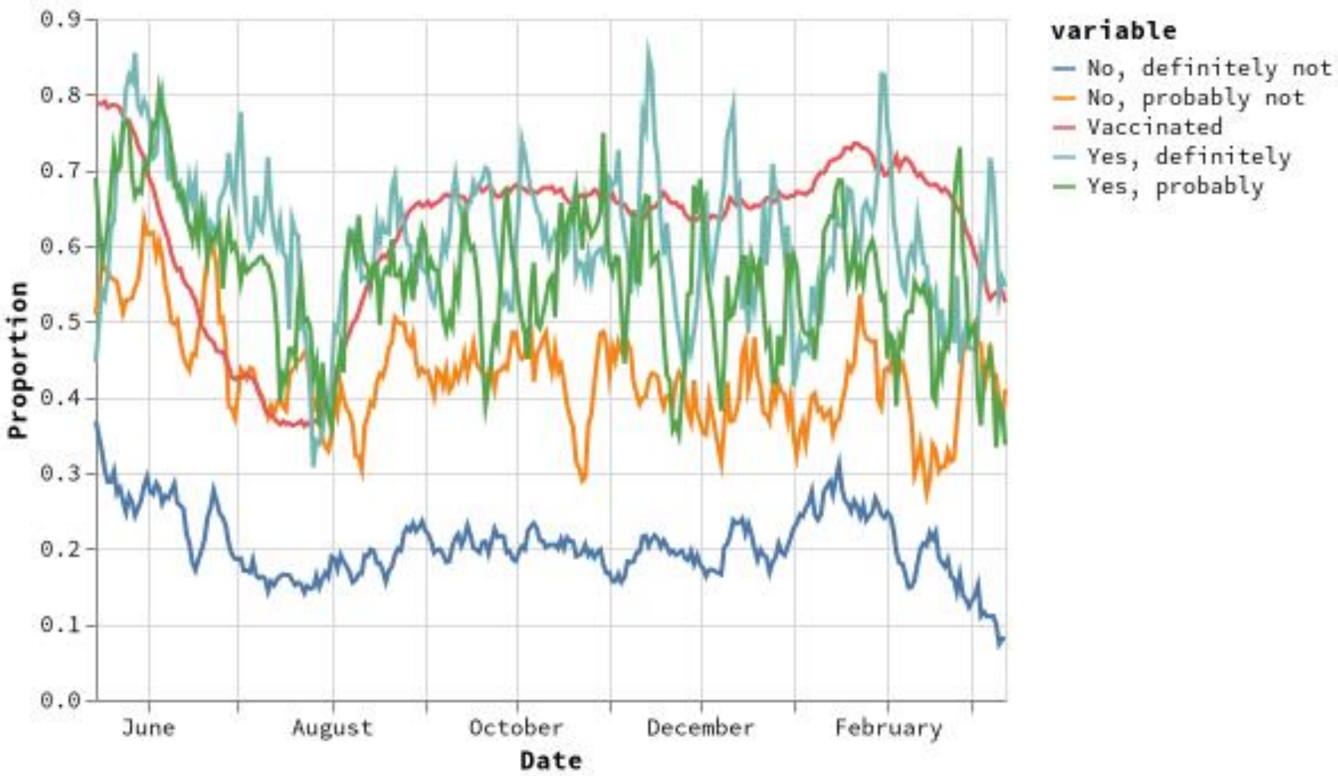
Data Source: https://covidcast.cmu.edu

Mask Usage Slows and Continues Decline

Self-reported mask usage drops to lowest levels since late August

- US and VA experienced similar decreases
- Mask wearing remains lower amongst unvaccinated especially among least willing to be vaccinated





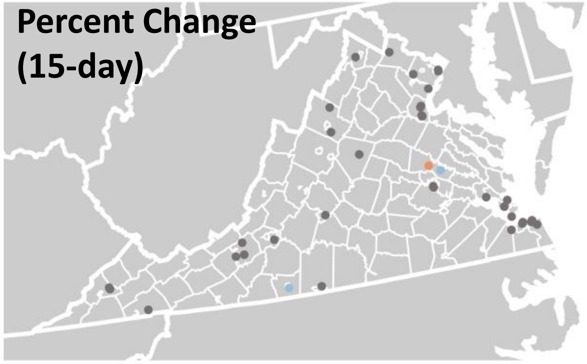
Data Source: https://covidcast.cmu.edu

Wastewater Monitoring

Wastewater provides a coarse early warning of COVID-19 levels in communities

- Most sites continue to detect COVID-19 in wastewater
- Some sites show declines slowing with some upticks in a a few of the coverage areas
- Mask wearing remains lower amongst unvaccinated especially among least willing to be vaccinated

Percent Change (15-day)



SARS-CoV-2 RNA wastewater levels, Virginia:
15-day percent change by sewershed

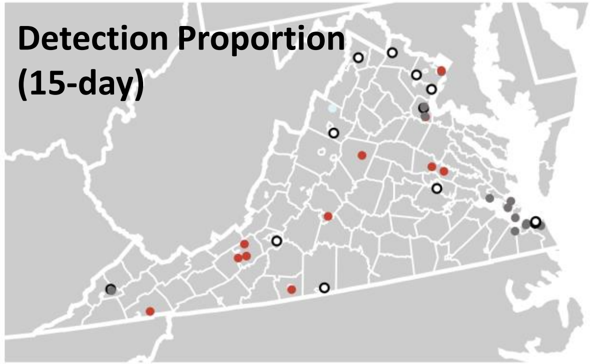
15-day % change category	Num. sites	% sites	Category change in last 7 days
-100%	0	0	N/A*
-99% to -10%	2	67	-89%
-9% to 0%	0	0	N/A*
1% to 9%	0	0	N/A*
10% to 99%	0	0	-100%
100% to 999%	1	33	0%
1000% or more	0	0	-100%

Total sites with current data: 3
Total number of wastewater sampling sites: 39

How is 15-day percent change calculated?

Select legend categories to filter points on the map.
-100% · -99% to -10% · -9% to 0% · 1% to 9% · 10% to 99% · 100% to 999% · 1000% or more · No recent data

Detection Proportion (15-day)



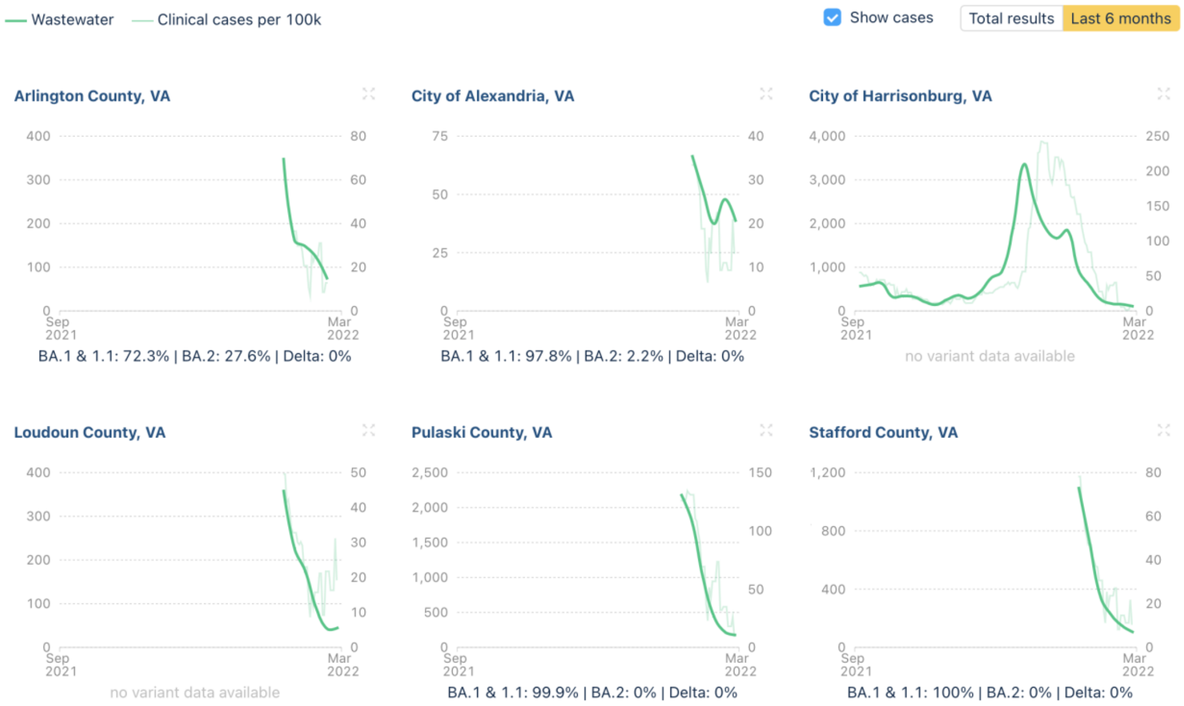
SARS-CoV-2 RNA wastewater levels, Virginia:
15-day detection proportion by sewershed

15-day detection % category	Num. sites	% sites	Category change in last 7 days
Non-Detect	14	54	600%
1% to 19%	0	0	N/A*
20% to 39%	0	0	N/A*
40% to 59%	1	4	-93%
60% to 79%	0	0	N/A*
80% to 100%	11	42	10%

Total sites with current data: 26
Total number of wastewater sampling sites: 39

How is 15-day detection proportion calculated?

Select legend categories to filter points on the map.
Non-detect · Less than 20% · 20% to 39% · 40% to 59% · 60% to 79% · 80% to 100% · No recent data



Sources: Wastewater data from Biobot Analytics, Inc.; Clinical data from USAFacts

Data Source: CDC Data Tracker

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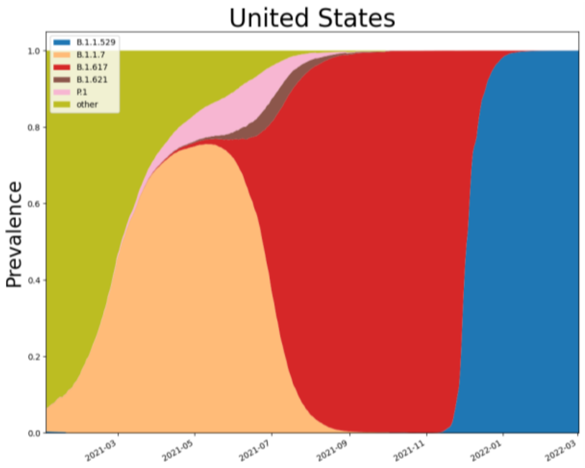
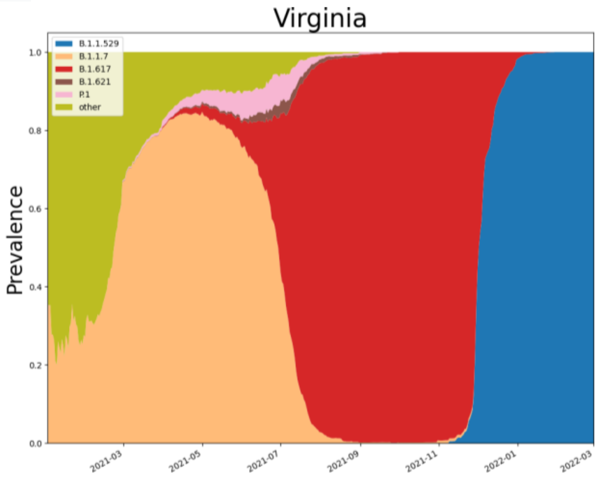
Data Source: https://biobot.io/data/

SARS-CoV2 Variants of Concern

Emerging new variants will alter the future trajectories of pandemic and have implications for future control

- Emerging variants can:
  - Increase transmissibility
  - Increase severity (more hospitalizations and/or deaths)
  - Limit immunity provided by prior infection and vaccinations
- Genomic surveillance remains very limited
  - Challenges ability to estimate impact in US to date and estimation of arrival and potential impact in future





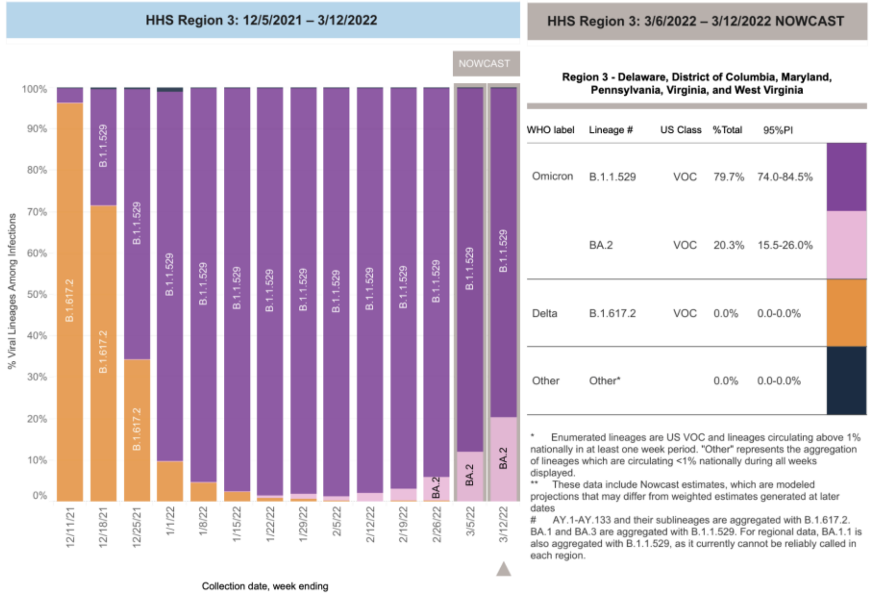
WHO label	Pango lineage•	GISAID clade	Nextstrain clade	Additional amino acid changes monitored°	Earliest documented samples	Date of designation
Alpha	B.1.1.7	GRY	20I (V1)	+S:484K +S:452R	United Kingdom, Sep-2020	18-Dec-2020
Beta	B.1.351	GH/501Y.V2	20H (V2)	+S:L18F	South Africa, May-2020	18-Dec-2020
Gamma	P.1	GR/501Y.V3	20J (V3)	+S:681H	Brazil, Nov-2020	11-Jan-2021
Delta	B.1.617.2	G/478K.V1	21A, 21I, 21J	+S:417N +S:484K	India, Oct-2020	VOI: 4-Apr-2021 VOC: 11-May-2021
Omicron*	B.1.1.529	GRA	21K, 21L	+R346K	Multiple countries, Nov-2021	VUM: 24-Nov-2021 VOC: 26-Nov-2021

World Health Organization [WHO](WHO)

Omicron Prevalence
CDC now tracking subvariant BA.2

CDC nowcast for week ending March 6th shows 20.3% BA.2 in Region 3, up from 12.7% previous week

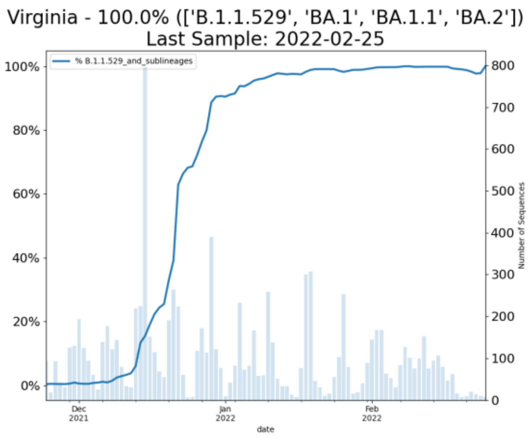
US tracking at 23% BA.2 from 14% last week

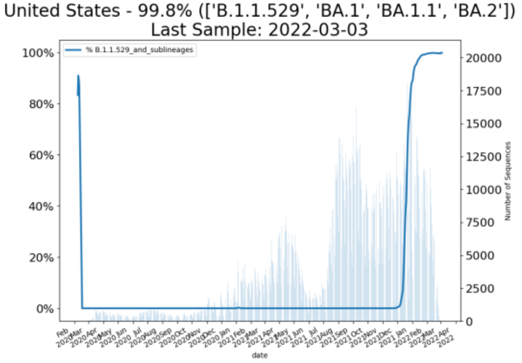


CDC Variant Tracking

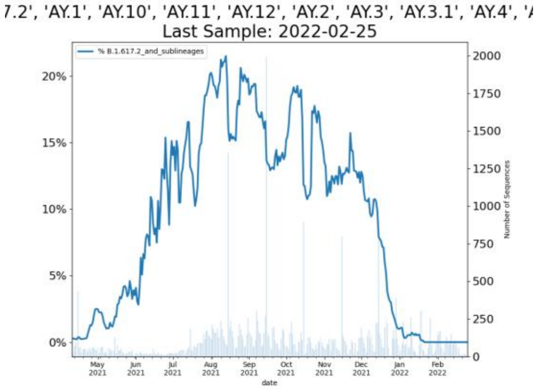
SARS-CoV2 Variants of Concern

Omicron ο - Lineage B.1.1.529



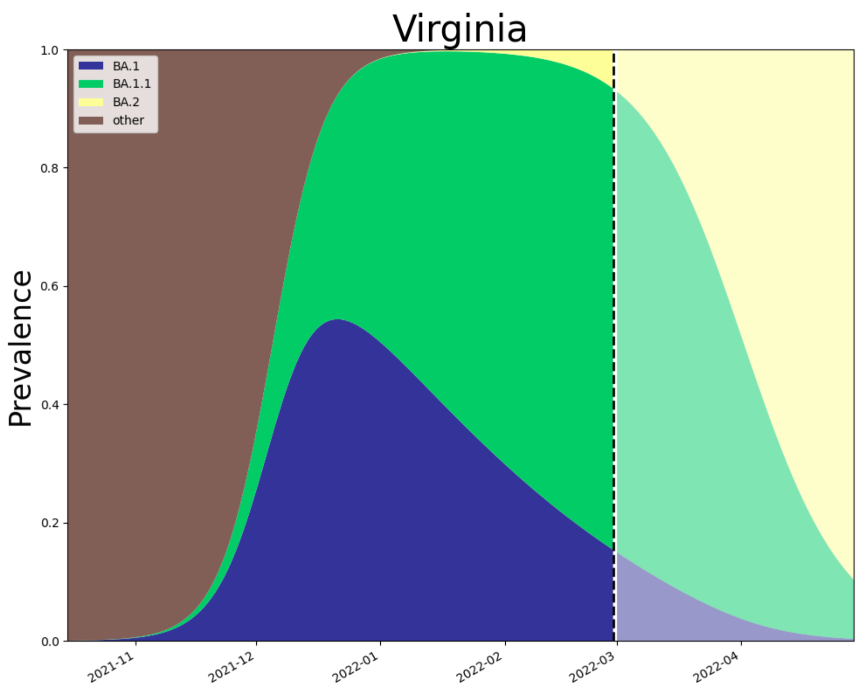


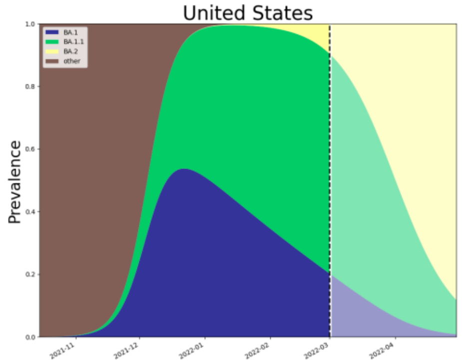
Delta δ - Lineage B.1.617.2



GISAID outbreak.info

VoC Polynomial Fit Projections

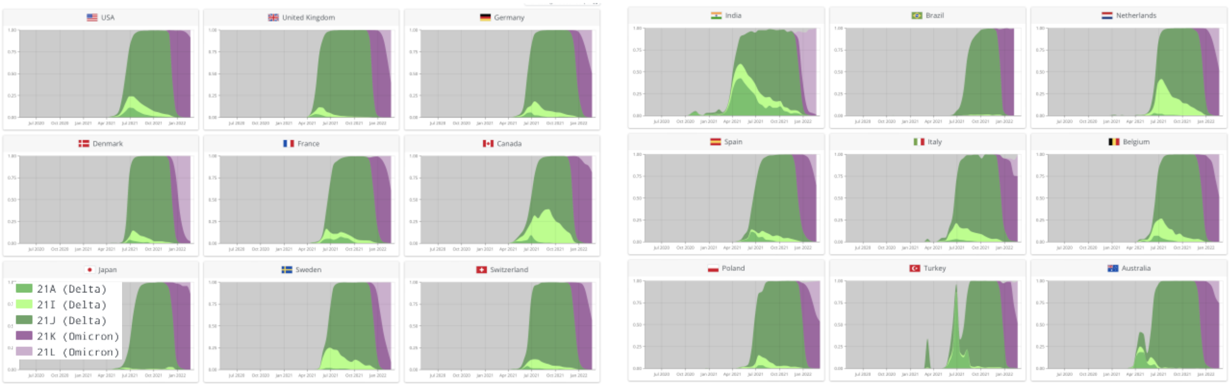




SARS-CoV2 BA.2 subvariant Tracking

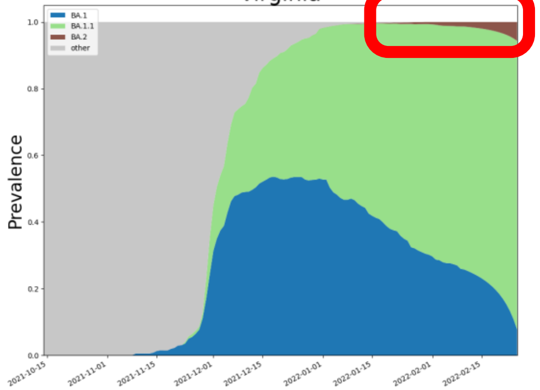
BA.2 subvariant growing rapidly in some European countries

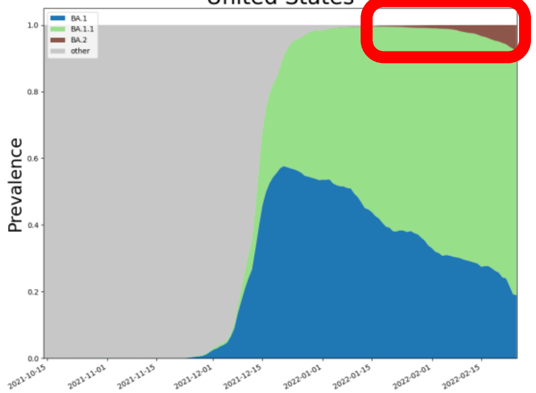
- Both Delta and the Omicron BA.2 subvariant don't have the SGTF signal with PCR tests, so the reduction caused by Omicron BA.1 SGTF can be an imperfect signal for increased BA.2
- Subvariant BA.2 in all HHS regions of USA, Region 3 (includes VA) has highest estimated prevalence
- BA.2 is now majority subvariant in most northern European countries and India and some neighbors



[CoVariants.org](https://covariants.org)

Whole Genomes in public repositories

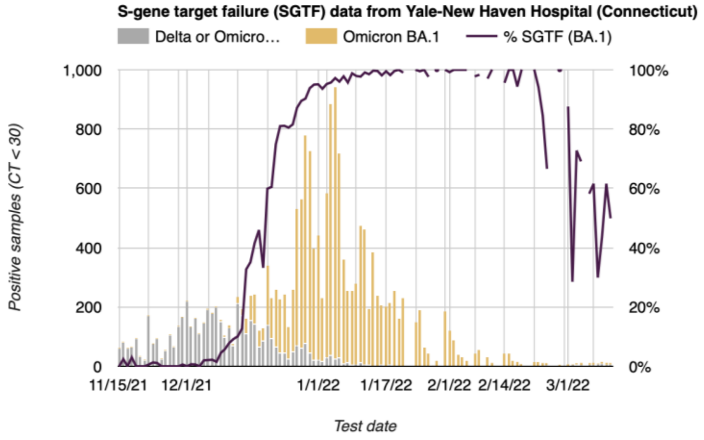




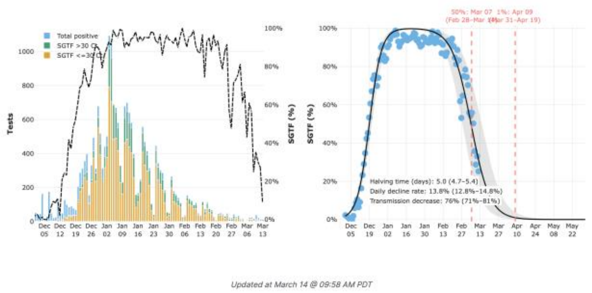
GISAID outbreak.info

SGTF proxy in US

[Yale- New Haven]()



[San Diego]()



Some drops in SGTF in CT and CA

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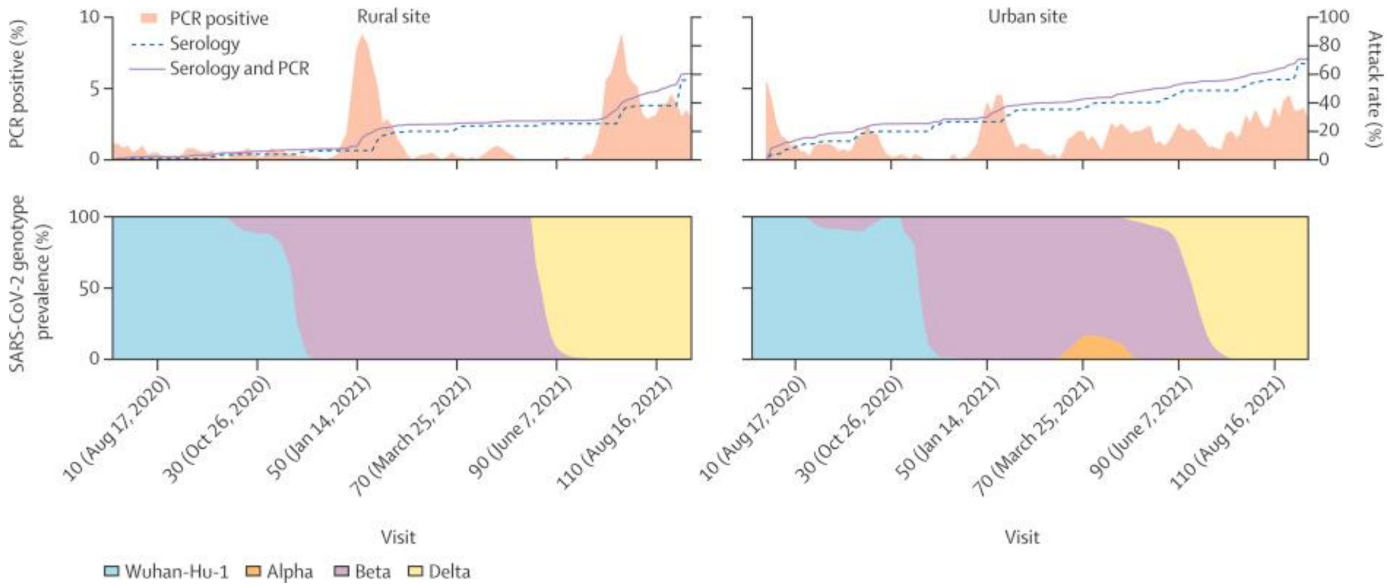
Pandemic Pubs

1. In S. Africa study 85·3% SARS-CoV-2 infections were asymptomatic and index case symptom status did not affect household cumulative infection risk
2. "Since Omicron began, every Covid case has been between 20 and 50 times more deadly in Hong Kong than in peer countries." Higher than even the pre-vaccine levels in England.
3. Adjusted secondary attack rates in both household and non-household settings were higher among contacts of cases with BA.2 than other Omicron.

1



In a study of 222 households, 1200 individuals, (643 at rural site and 557 at urban site) using 115,759 nasal specimens from (follow-up 92.5%). By RT-rtPCR and serology combined, 749 of 1200 individuals (62·4% [95% CI 58·1–66·4]) had at least one SARS-CoV-2 infection episode, and 87 of 749 (11·6% [9·4–14·2]) were reinfected. Increased household transmission of beta and delta variants was likely to have contributed to successive waves of SARS-CoV-2 infection, with more than 60% of individuals infected by the end of follow-up.
https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(22)00069-X/fulltext

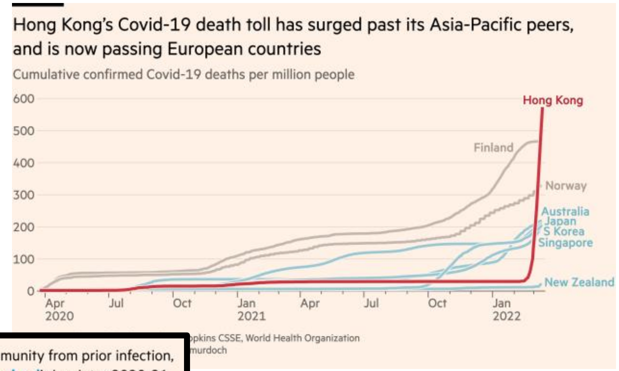
3

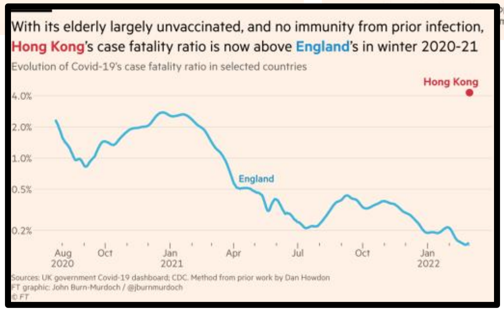
Table 4. Secondary attack rates for contacts of cases with confirmed sequenced VUI-22JAN-01 and all other Omicron (VOC-21NOV-01)
(Case test dates 1 January to 14 February 2022, variant data as of 7 March 2022 and contact tracing data as of 8 March 2022)

Variant	Setting	Number of exposing cases	Number of contacts	Adjusted* secondary attack rate (95% Confidence Interval)
VOC-21NOV-01	Household	178,069	369,011	10.7% (10.6%-10.8%)
VUI-22JAN-01	Household	20,072	41,621	13.6% (13.2%-14.0%)
VOC-21NOV-01	Non-household	30,325	74,343	4.2% (4.0%-4.3%)
VUI-22JAN-01	Non-household	3,565	8,763	5.3% (4.7%-5.8%)

Secondary attack rates and odds ratios are based on positive tests amongst contacts named to NHS Test and Trace by an original case identified with sequenced confirmed BA.2 (VUI-22JAN-01) or other sequenced confirmed Omicron (VOC-21NOV-01, primarily BA.1)
with date of symptom onset or positive test of the secondary case occurring 2 to 14 days after original exposure.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1060337/Technical-Briefing-38-11March2022.pdf

2





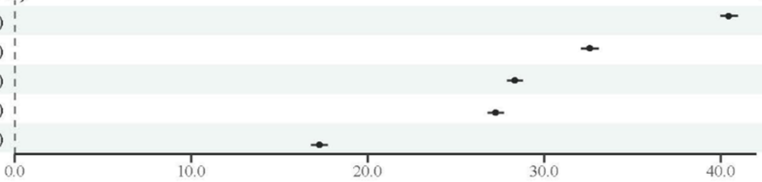
Financial Times via John Burn-Murdoch

Pandemic Pubs (last week)

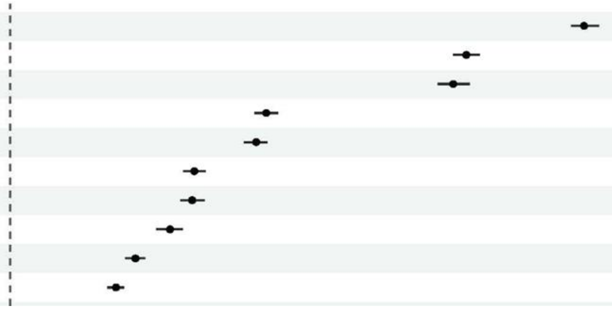
1. Denmark at the population-level, where the majority of test-positives (96.0%) were not hospitalized during acute infection, a considerable proportion experience post-acute symptoms and sequelae 6-12 months after infection.
2. CDC officially advises 12-39 yo males to consider a 8 week interval between 1st and 2nd dose vaccines, and broadens the recommended interval for all 12 and over.
3. During Omicron dominance the effectiveness against cases of BNT162b2 declined rapidly for children, particularly those 5-11 years. However, vaccination of children 5-11 years was protective against severe disease and is recommended.
4. Qatar study shows infection with one Omicron sub-lineage induces "strong, but not full protection" against reinfection from another.

1

Health problem	Positive (n,%)	Negative (n,%)	Risk Difference (95% CI)
Physical exhaustion	25,492 (45.5%)	5,879 (7.3%)	40.45 (39.99, 40.97)
Mental exhaustion	20,810 (37.7%)	5,877 (7.4%)	32.58 (32.11, 33.09)
Difficulties concentrating	16,720 (29.7%)	2,812 (3.4%)	28.34 (27.91, 28.78)
Memory issues	16,149 (28.7%)	3,057 (3.7%)	27.25 (26.80, 27.71)
Sleep problems	11,850 (22.9%)	4,936 (6.5%)	17.27 (16.81, 17.73)



Symptom	Positive (n,%)	Negative (n,%)	Risk Difference (95% CI)
Dysosmia	6,674 (10.9%)	604 (0.7%)	10.92 (10.68, 11.21)
Dysgeusia	5,365 (8.8%)	551 (0.6%)	8.68 (8.43, 8.93)
Fatigue/exhaustion	6,799 (11.1%)	2,868 (3.1%)	8.43 (8.14, 8.74)
Dyspnea	3,277 (5.4%)	813 (0.9%)	4.87 (4.65, 5.09)
Reduced strength legs/arms	3,381 (5.5%)	1,024 (1.1%)	4.68 (4.45, 4.89)
Sleeping legs/arms	2,841 (4.7%)	1,236 (1.3%)	3.50 (3.29, 3.72)
Muscle/joint pain	3,217 (5.3%)	1,772 (1.9%)	3.46 (3.24, 3.69)
Headache	3,740 (6.1%)	2,868 (3.1%)	3.04 (2.78, 3.28)
Dizziness	2,430 (4.0%)	1,495 (1.6%)	2.38 (2.18, 2.57)
Chest pain	1,695 (2.8%)	780 (0.8%)	2.01 (1.85, 2.16)



Denmark nationwide cross-sectional study including 152,880 individuals aged 15-years or older. Data were collected 6, 9 or 12 months after the test using web-based questionnaires. More than half (53.1%) of test-positives reported at least one of the following conditions: concentration difficulties, memory issues, sleep problems, mental or physical exhaustion, compared to 11.5% of test-negatives.
https://www.medrxiv.org/content/10.1101/2022.02.27.22271328v1.full.pdf

2

TABLE 2. COVID-19 vaccination schedule for the primary series in the general population*

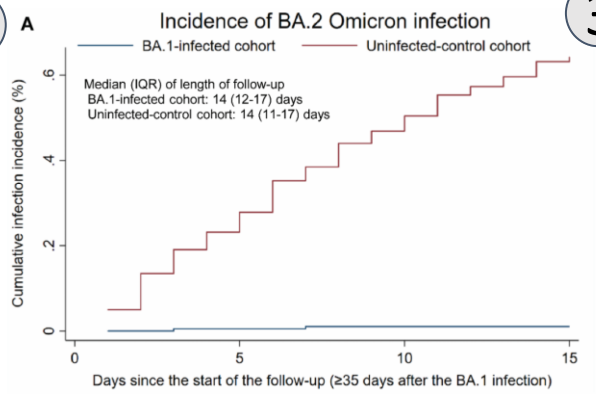
Primary series vaccine manufacturer	Age group	Number of doses in primary series	Number of booster doses	Interval between 1st and 2nd dose	Interval between primary series and booster dose
Pfizer-BioNTech	5–11 years	2	NA	3 weeks	NA
Pfizer-BioNTech	≥12 years	2	1	3-8 weeks†	≥5 months
Moderna	≥18 years	2	1	4-8 weeks†	≥5 months
Janssen	≥18 years	1	1	NA	≥2 months

*For the vaccination schedule for people who are moderately or severely immunocompromised, see Table 3

†An **8-week** interval may be optimal for some people ages 12 years and older, especially for males ages 12 to 39 years. A **shorter interval** (3 weeks for Pfizer-BioNTech; 4 weeks for Moderna) between the first and second doses remains the recommended interval for: people who are moderately to severely immunocompromised; adults ages 65 years and older; and others who need rapid protection due to increased concern about community transmission or risk of severe disease.

CDC recently updated guidance on vaccinations to acknowledge an 8-week interval between doses may be optimal for those 12 years and older,
https://www.cdc.gov/vaccines/covid-19/clinical-considerations/covid-19-vaccines-us.html#primary-series

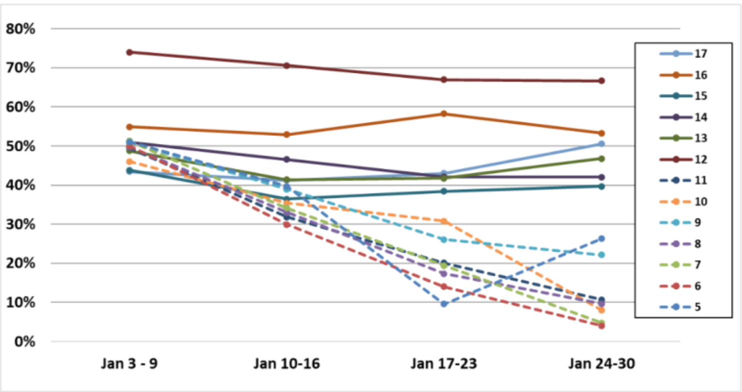
4



Qatar: Two national matched, retrospective cohort studies were conducted to estimate effectiveness of BA.1 infection against reinfection with BA.2 (N=20,197; BA.1-against-BA.2 study), and effectiveness of BA.2 infection against reinfection with BA.1 (N=100,925; BA.2-against-BA.1 study). **BA.1 is 94.9% effective against BA.2; BA.2 is 85.6% effectives against BA.1**
https://www.medrxiv.org/content/10.1101/2022.02.24.22271440v1

3

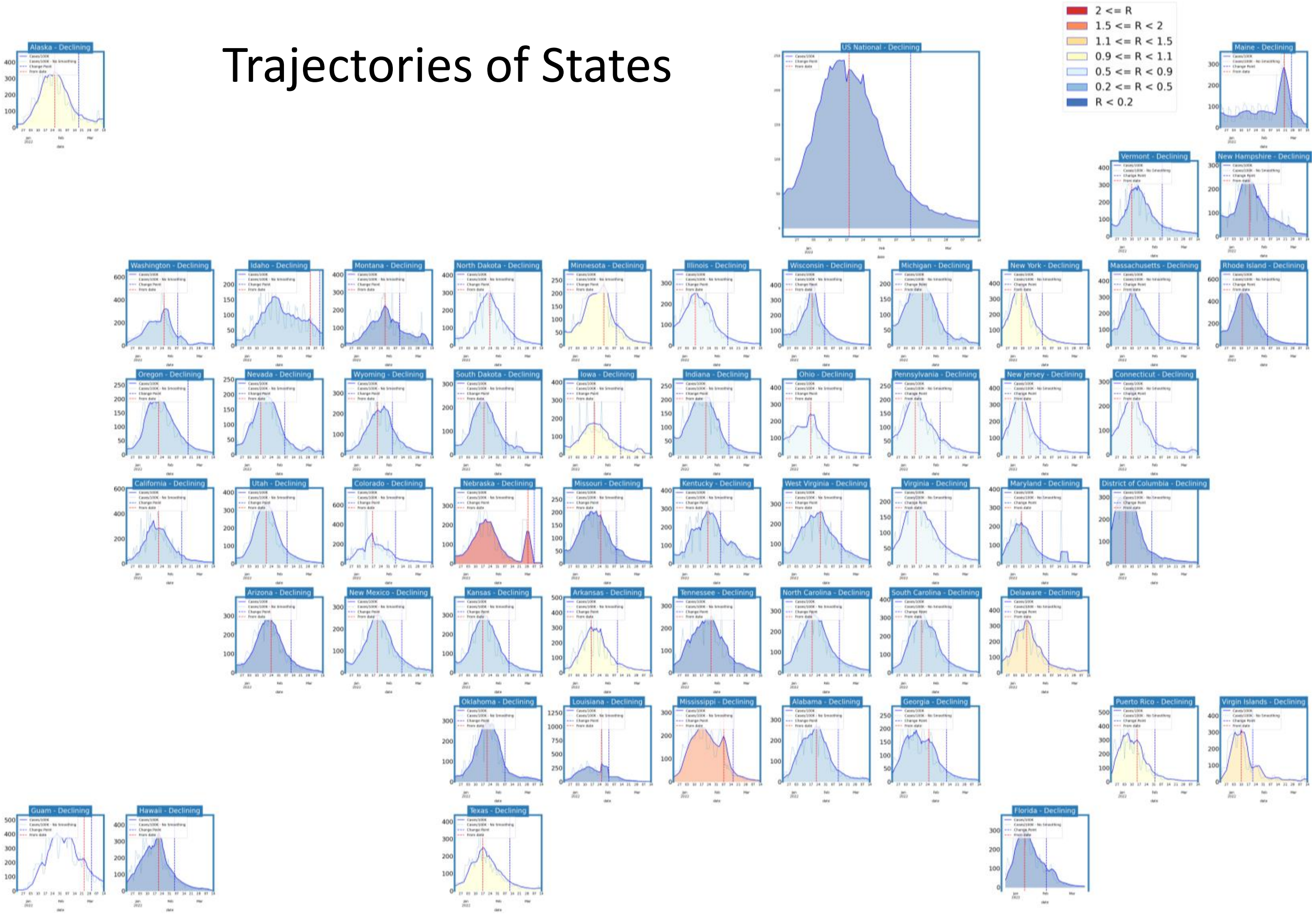
Figure 1: Vaccine Effectiveness against Infection, by Week and Year of Age



Incidence rate ratios, comparing cases during January 3 - January 30, 2022 for unvaccinated versus children newly fully-vaccinated December 13, 2021-January 2, 2022, by time Since Full Vaccination. Possible relationship between CDC recommended dosing in #2 and demonstrated waning in younger age groups
https://www.medrxiv.org/content/10.1101/2022.02.25.22271454v1

United States Case Rates

- All states have shifted to a declining trajectory

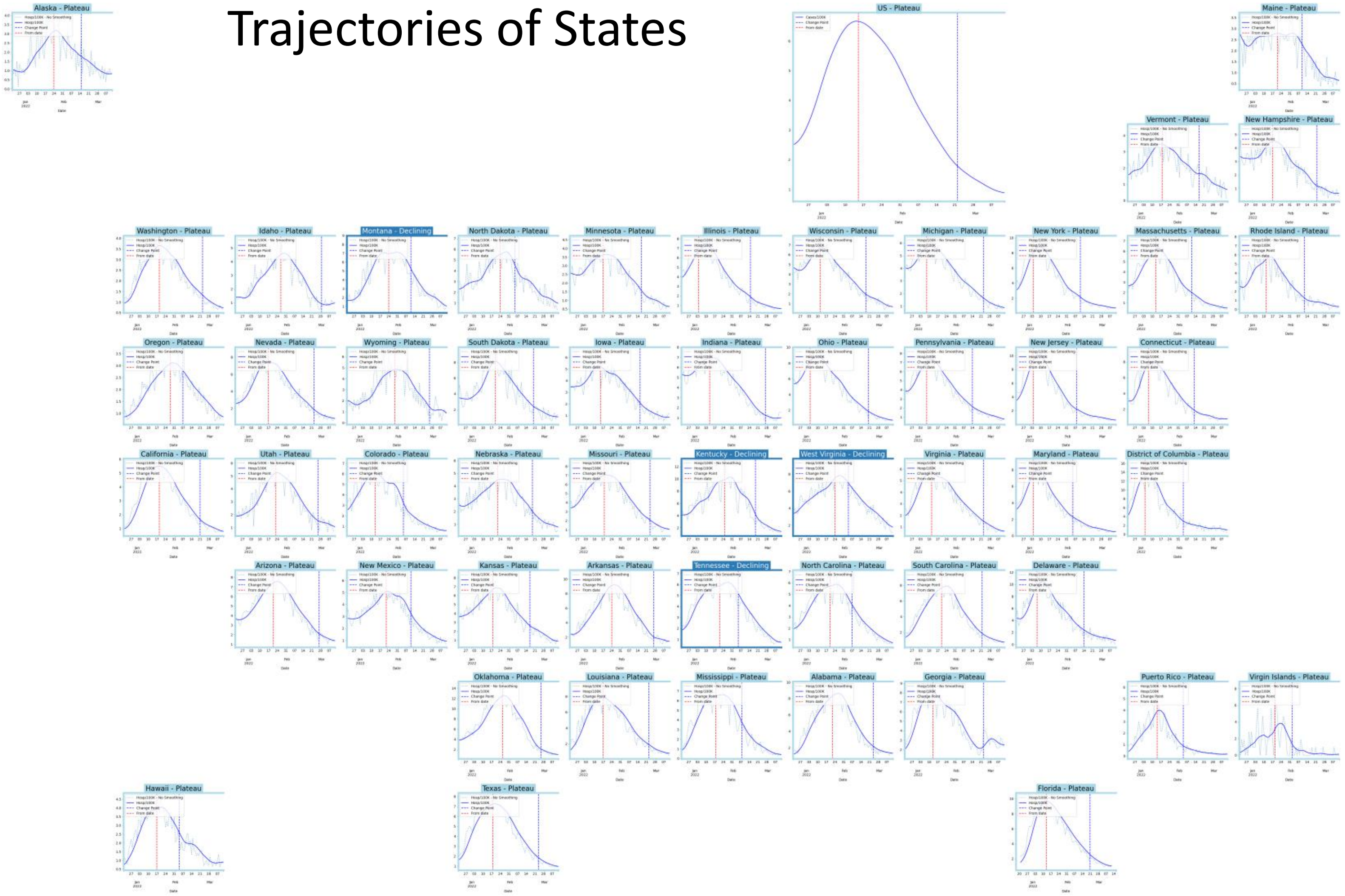


Status	# States
Declining	54 (54)
Plateau	0 (0)
Slow Growth	0 (0)
In Surge	0 (0)

United States Hospitalizations

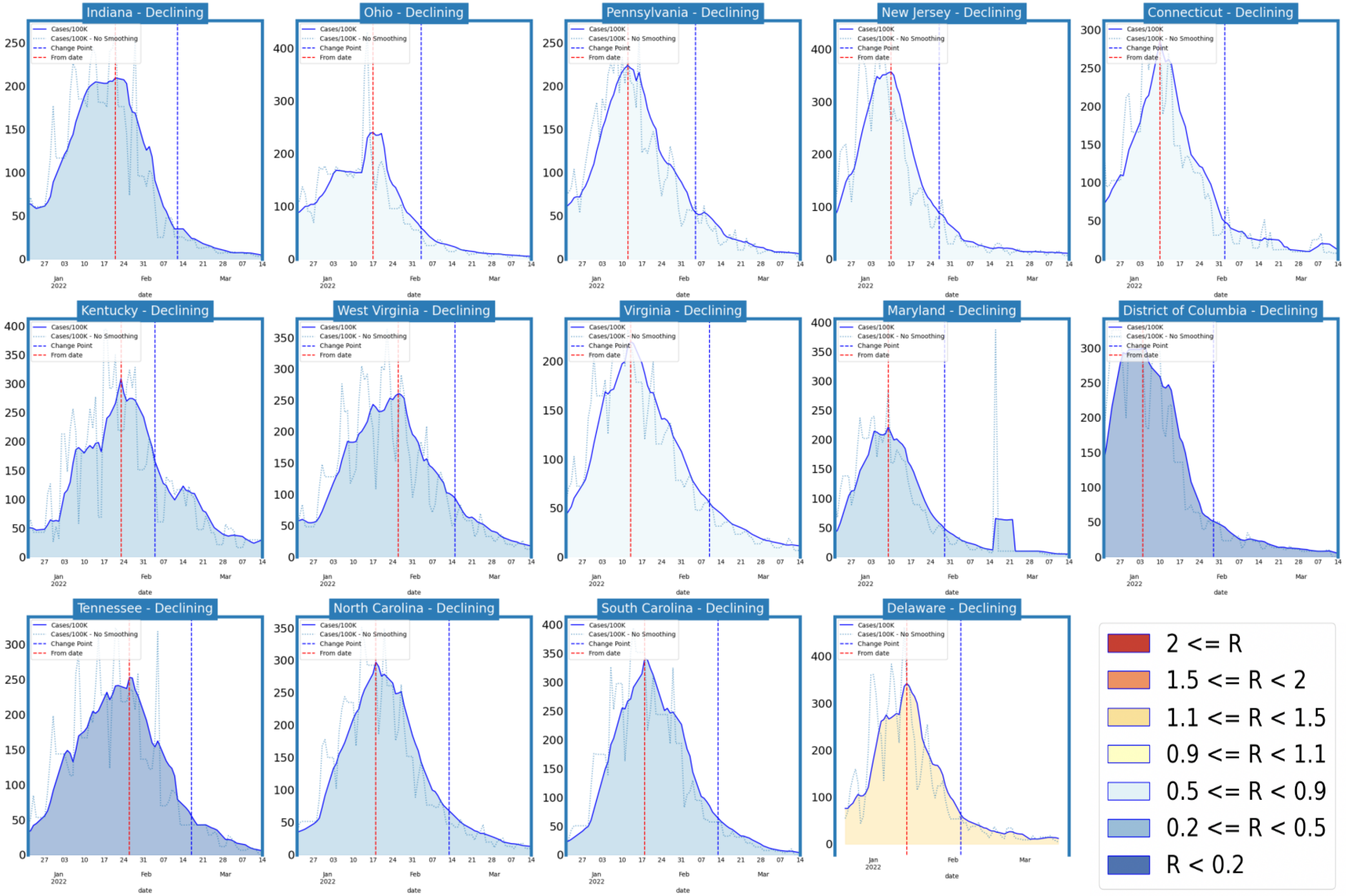
- Hospital admissions are lagging case rates, and have mainly entered plateaus
- Many states in growth trajectories show signs of slowing

Status	# States
Declining	4 (15)
Plateau	49 (37)
Slow Growth	0 (1)
In Surge	0 (0)



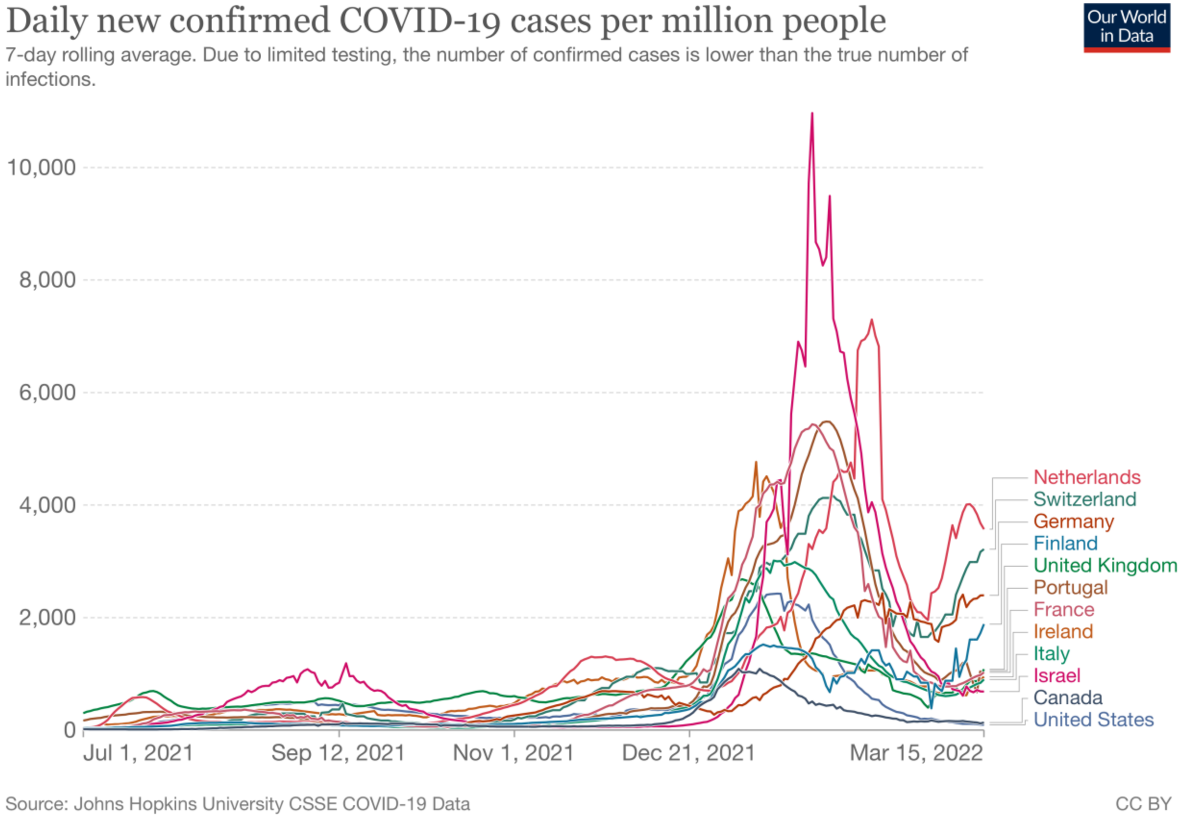
Virginia and Her Neighbors

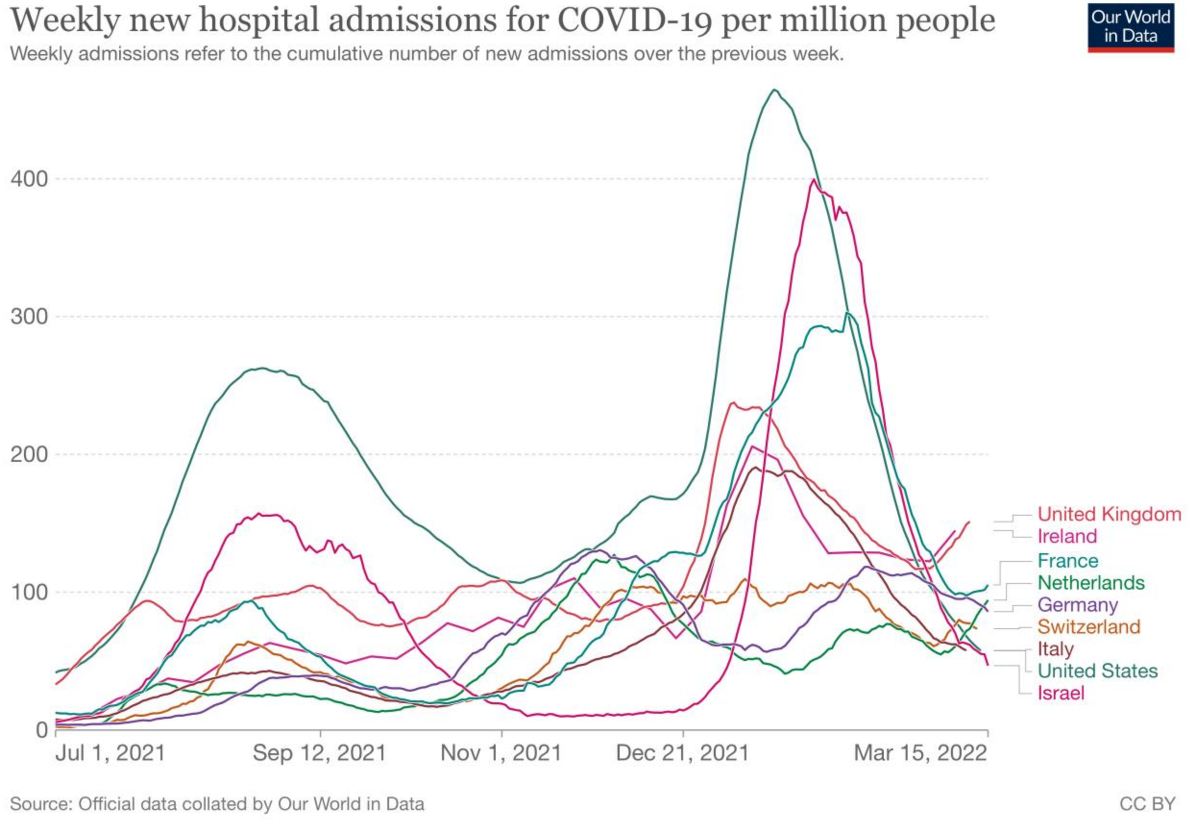
- All have dramatically dropped from peaks
- Rates have moderated
- All but Kentuky are below 25/100K, and most are finally below 10/100K



Other Countries

- Many, but not all, European countries are experiencing a rebound in cases
- Rebound in hospitalizations is a bit delayed but observed in some of these countries as well
- US per capita hospitalization rates lower than most European nations





Our World in Data

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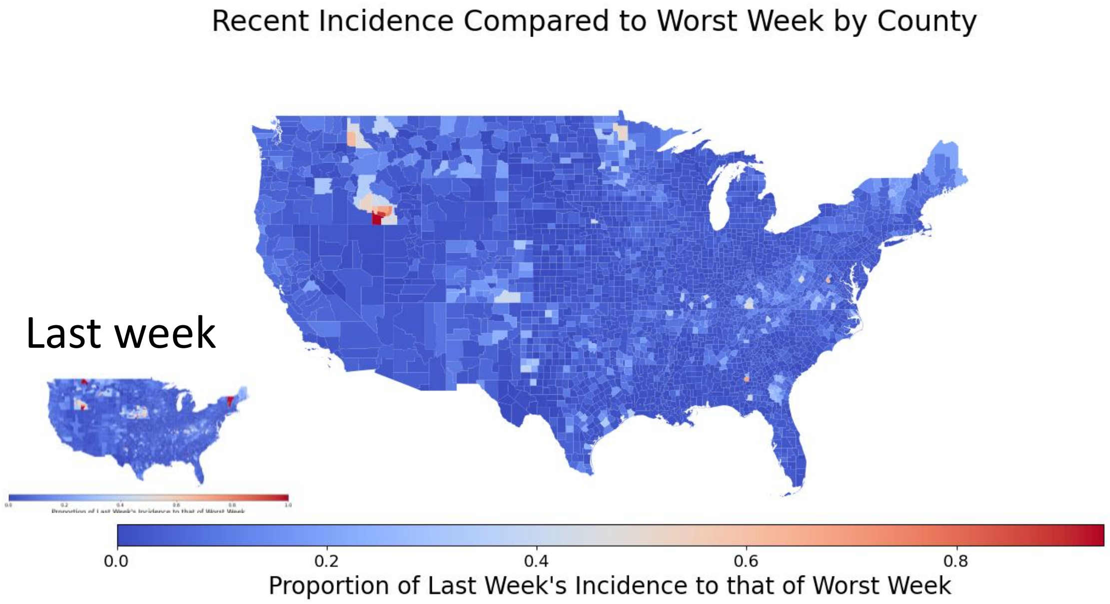
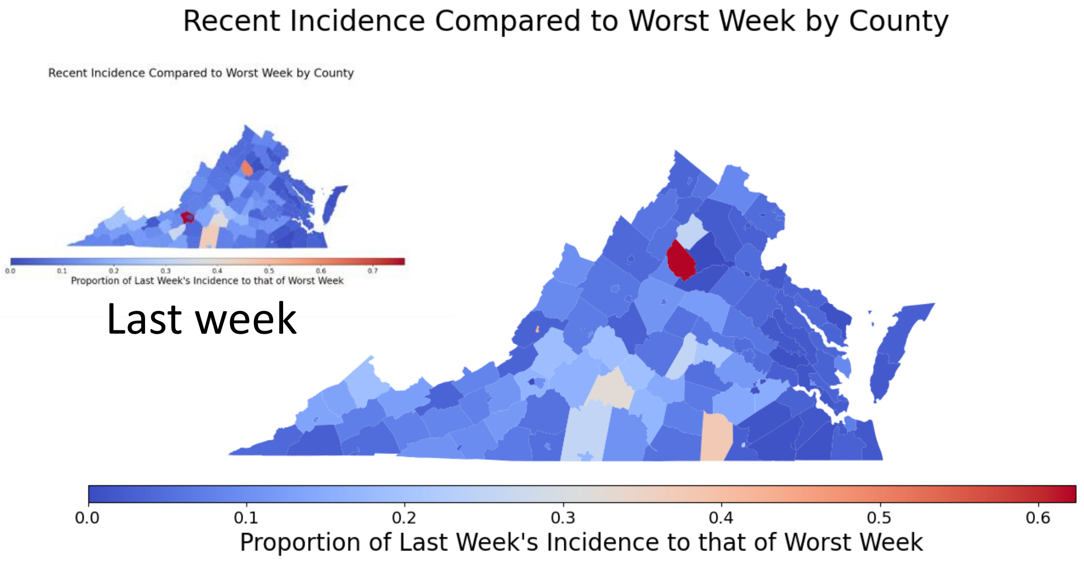
County-level comparison to previous highest peak

- Most counties in VA have had the highest case rate of the pandemic in the last week
- Nationally the number of counties at their highest rate has expanded considerably





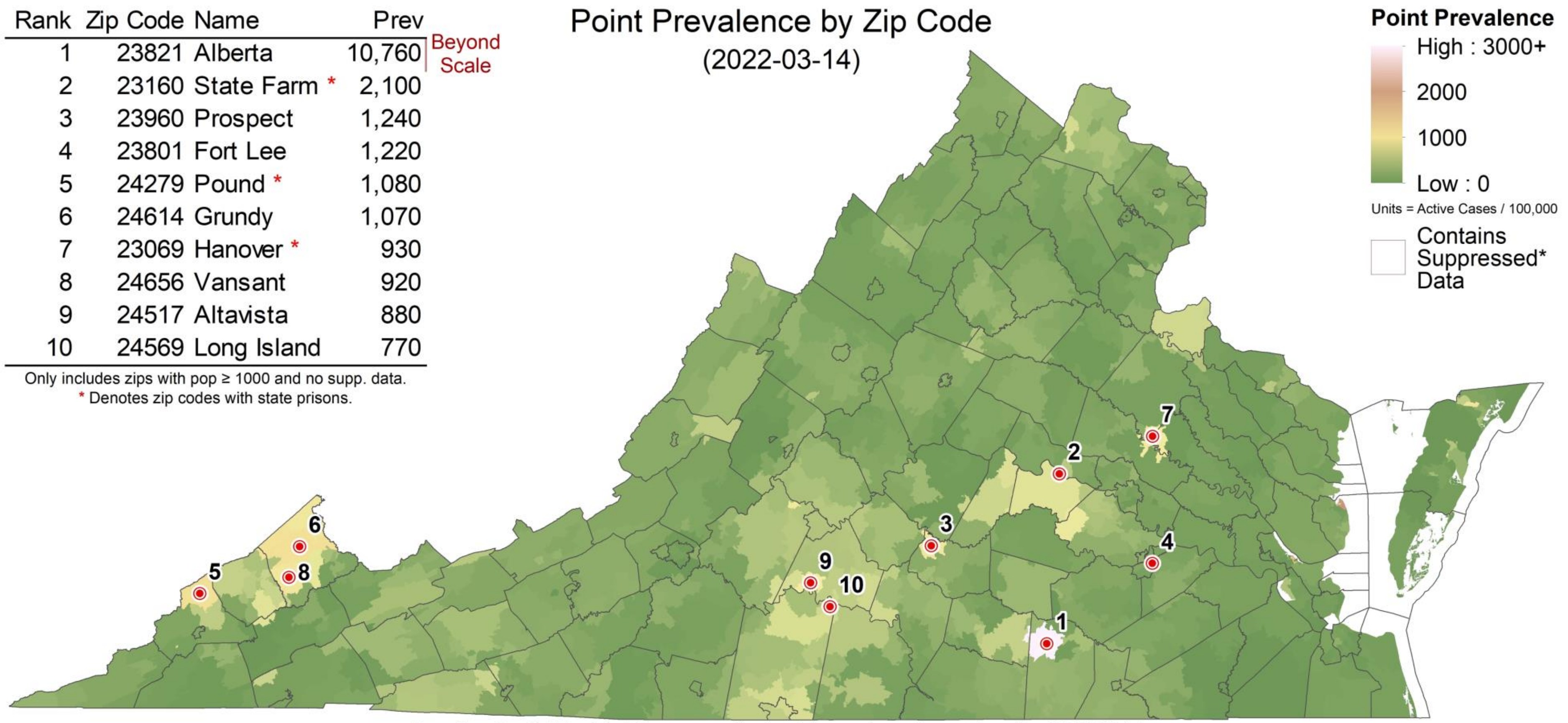
Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Clusters of high prevalence in Southwest
- Some counts are low and suppressed to protect anonymity, those are shown in white

Rank	Zip Code	Name	Prev
1	23821	Alberta	10,760 Beyond Scale
2	23160	State Farm *	2,100
3	23960	Prospect	1,240
4	23801	Fort Lee	1,220
5	24279	Pound *	1,080
6	24614	Grundy	1,070
7	23069	Hanover *	930
8	24656	Vansant	920
9	24517	Altavista	880
10	24569	Long Island	770

Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.



Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2022-03-14.

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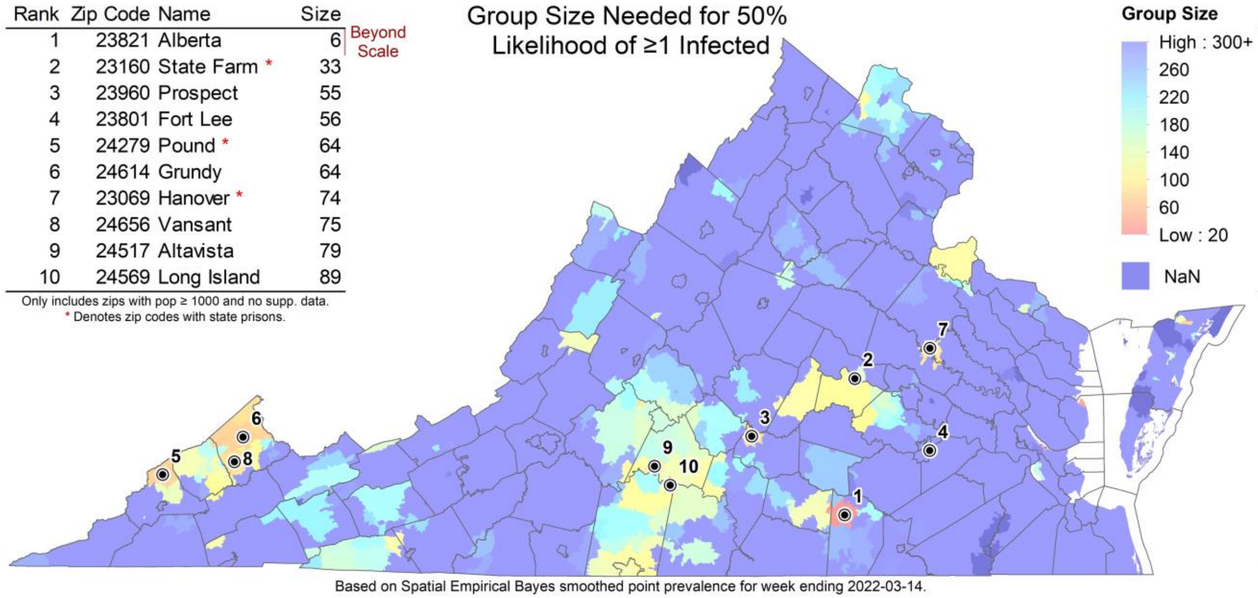
Risk of Exposure by Group Size and HCW prevalence

Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25)

- **Group Size**: Assumes 2 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey), and shows minimum size of a group with a 50% chance an individual is infected by zip code (eg in a group of 6 in Alberta, there is a 50% chance someone will be infected)
- **HCW ratio**: Case rate among health care workers (HCW) in the last week using patient facing health care workers as the denominator / general population's case prevalence

Rank	Zip Code	Name	Size
1	23821	Alberta	6 (Beyond Scale)
2	23160	State Farm *	33
3	23960	Prospect	55
4	23801	Fort Lee	56
5	24279	Pound *	64
6	24614	Grundy	64
7	23069	Hanover *	74
8	24656	Vansant	75
9	24517	Altavista	79
10	24569	Long Island	89

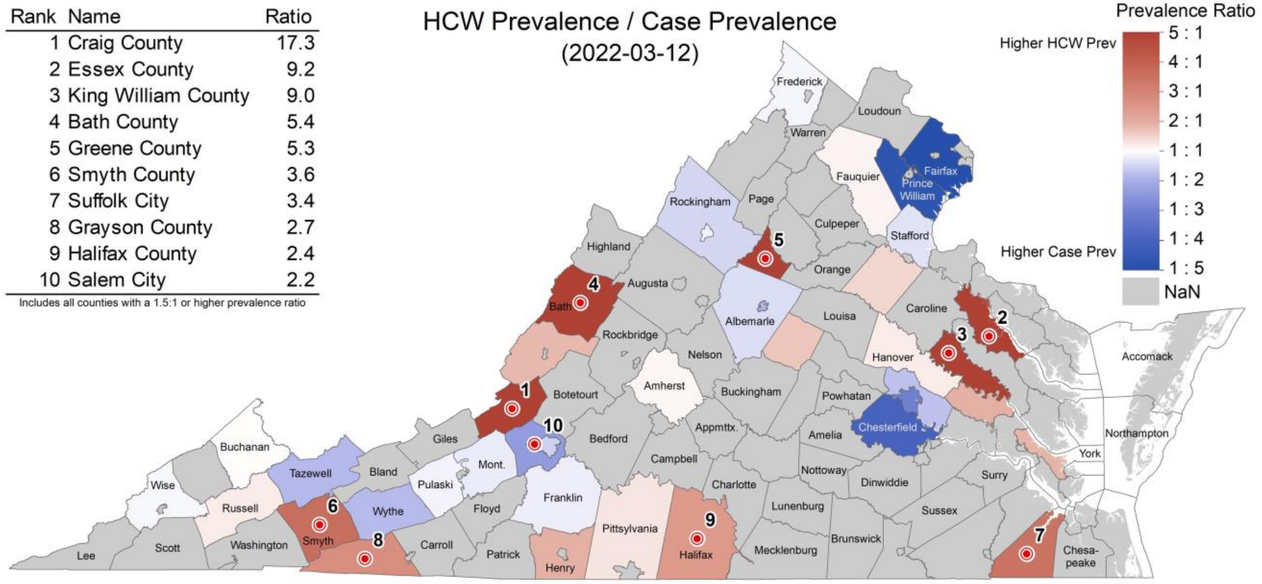
Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.



Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2022-03-14.

Rank	Name	Ratio
1	Craig County	17.3
2	Essex County	9.2
3	King William County	9.0
4	Bath County	5.4
5	Greene County	5.3
6	Smyth County	3.6
7	Suffolk City	3.4
8	Grayson County	2.7
9	Halifax County	2.4
10	Salem City	2.2

Includes all counties with a 1.5:1 or higher prevalence ratio



Current Hot-Spots

Case rates that are significantly different from neighboring areas or model projections

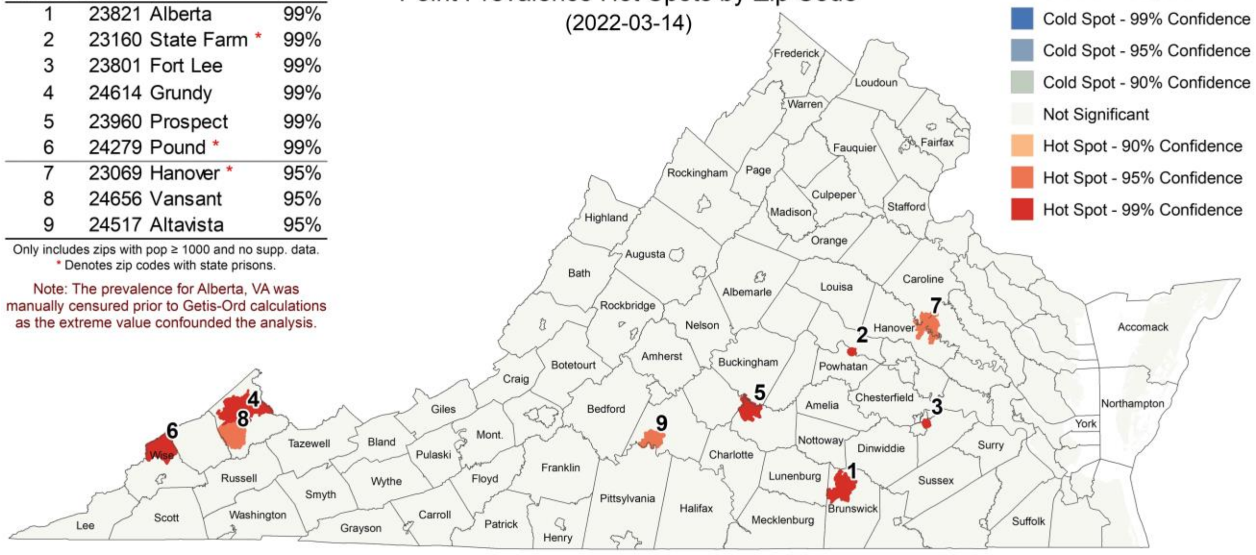
- **Spatial**: Getis-Ord Gi* based hot spots compare clusters of zip codes with weekly case prevalence higher than nearby zip codes to identify larger areas with statistically significant deviations
- **Temporal**: The weekly case rate (per 100K) projected last week compared to observed by county, which highlights temporal fluctuations that differ from the model's projections

Spatial Hotspots

Spot	Zip Code	Name	Conf.
1	23821	Alberta	99%
2	23160	State Farm *	99%
3	23801	Fort Lee	99%
4	24614	Grundy	99%
5	23960	Prospect	99%
6	24279	Pound *	99%
7	23069	Hanover *	95%
8	24656	Vansant	95%
9	24517	Altavista	95%

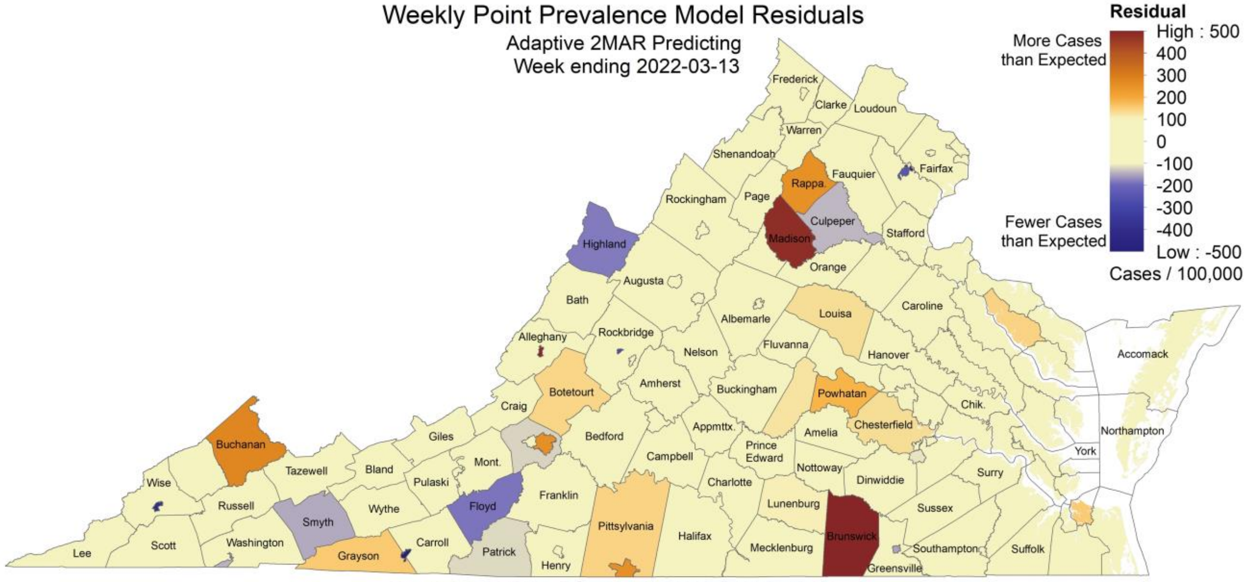
Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.

Note: The prevalence for Alberta, VA was manually censured prior to Getis-Ord calculations as the extreme value confounded the analysis.



Based on Global Empirical Bayes smoothed point prevalence for week ending 2022-03-14.

Clustered Temporal Hotspots

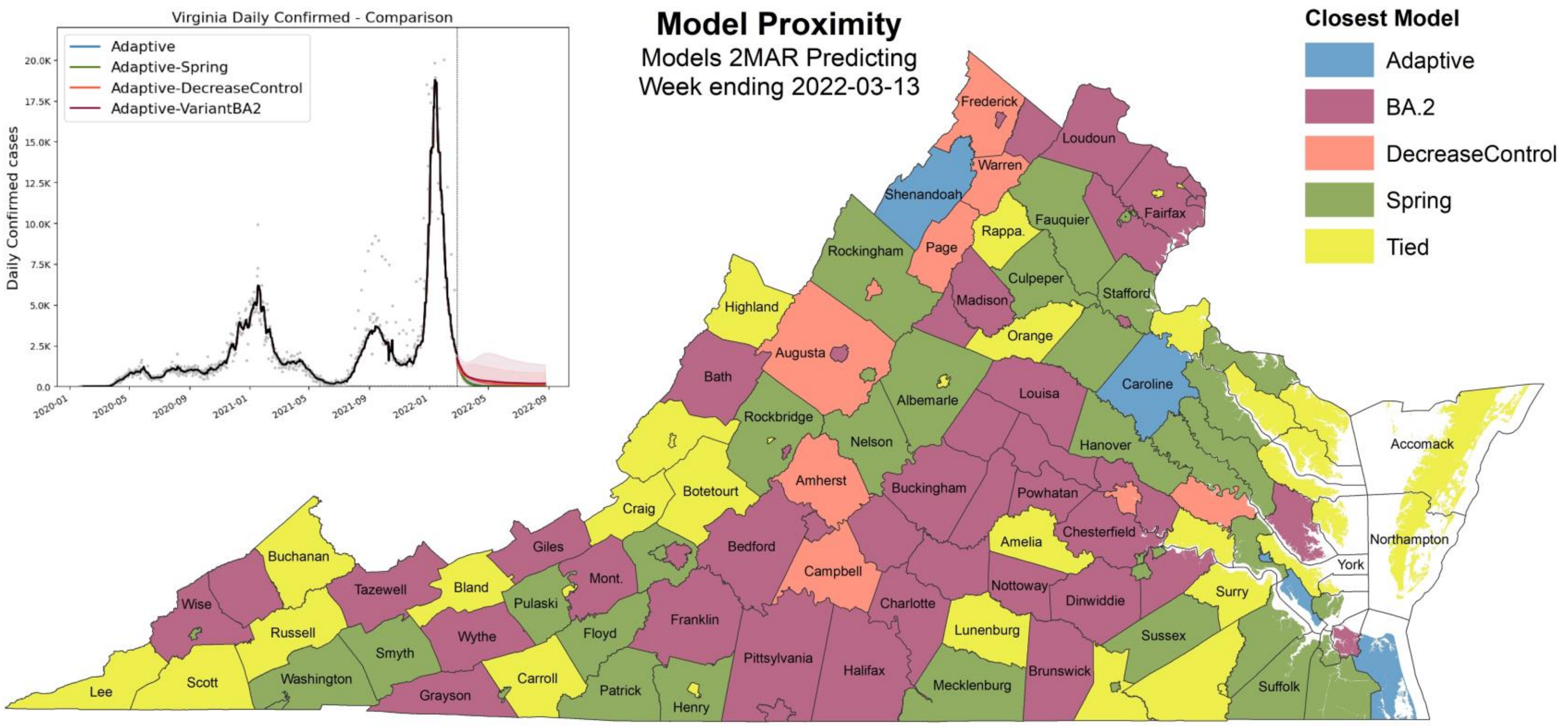


Moran's I = -0.016215, Z-Score = -0.439262, P-Value = 0.660472
No Residual Autocorrelation Detected

Scenario Trajectory Tracking

Which scenario from last projection did each county track closest?

- Minimal difference between projections overall
- Mixed results reflective of similarity of scenarios, most counties tracking slower decline scenarios (BA2 and DecreaseControl)

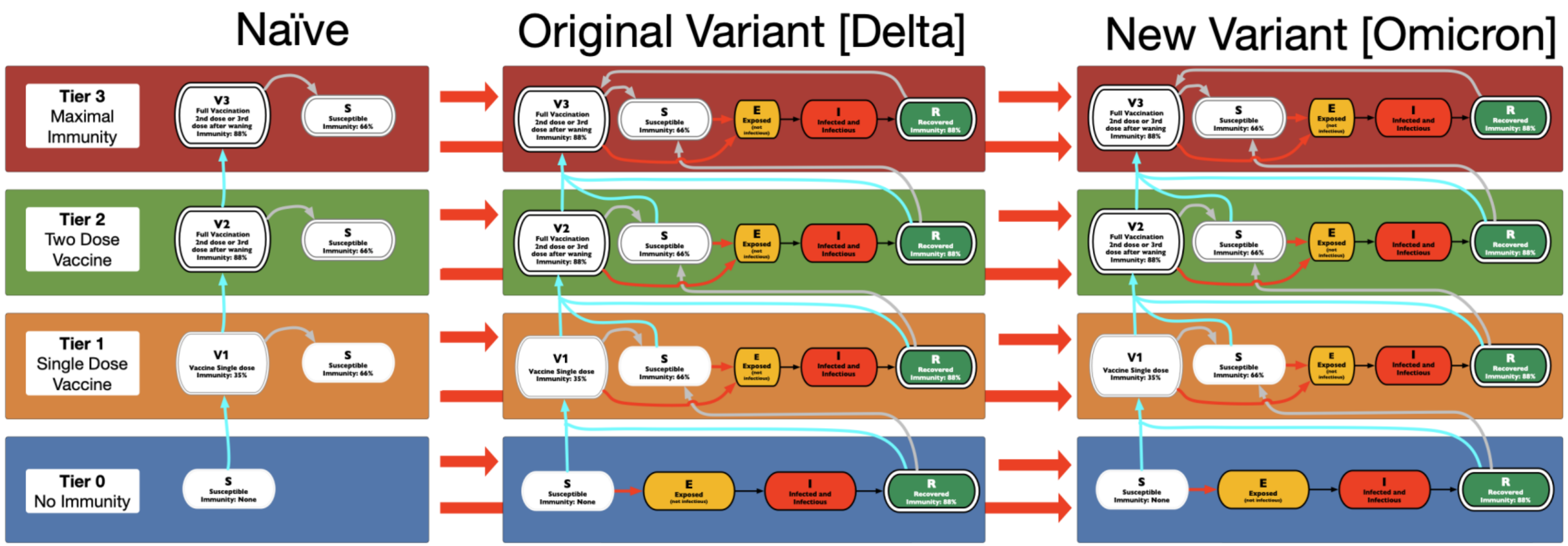


Model Update – Adaptive Fitting

Model Structure Extended for Multiple Strains

Omicron escapes immunity from vaccinated and those infected with Delta

- Multiple strain support allows representation of differential protection based on immunological history
- Severity of Outcomes varies by strain and level of immunity, thus allowing model to better capture hospitalizations and deaths from Omicron
- Adaptive fitting approach continues to use simulation to generate the full distribution of immune states across the population



Adaptive Fitting Approach

Each county fit precisely, with recent trends used for future projection

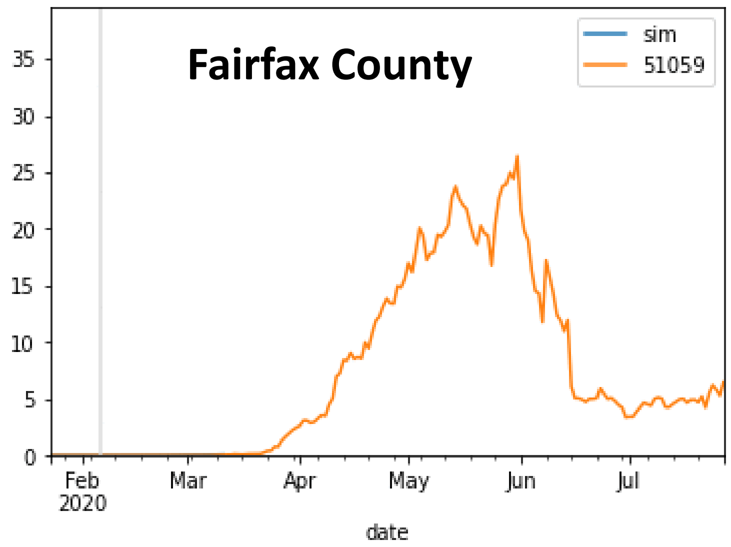
- Allows history to be precisely captured, and used to guide bounds on projections

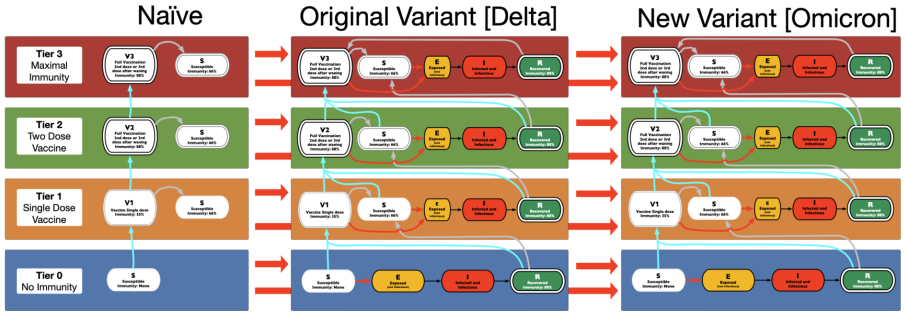
Model: An alternative use of the same meta-population model, PatchSim with multiple tiers of immunity

  - Allows for future "what-if" Scenarios to be layered on top of calibrated model
  - Allows for waning of immunity and for partial immunity against different outcomes (eg lower protection for infection than death)

External Seeding: Steady low-level importation

  - Widespread pandemic eliminates sensitivity to initial conditions, we use steady 1 case per 10M population per day external seeding





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Using Ensemble Model to Guide Projections

Ensemble methodology that combines the Adaptive with machine learning and statistical models such as:

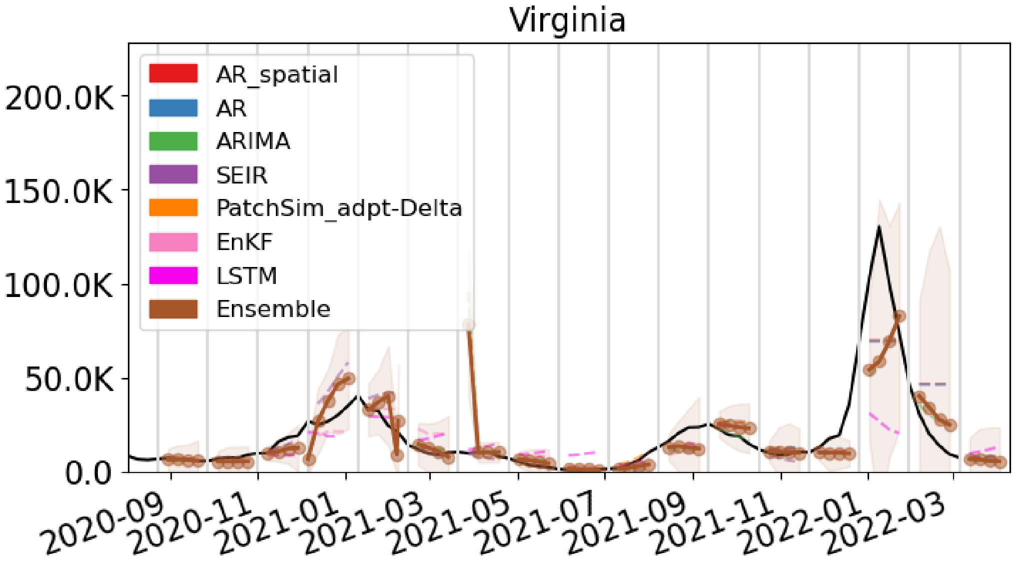
- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

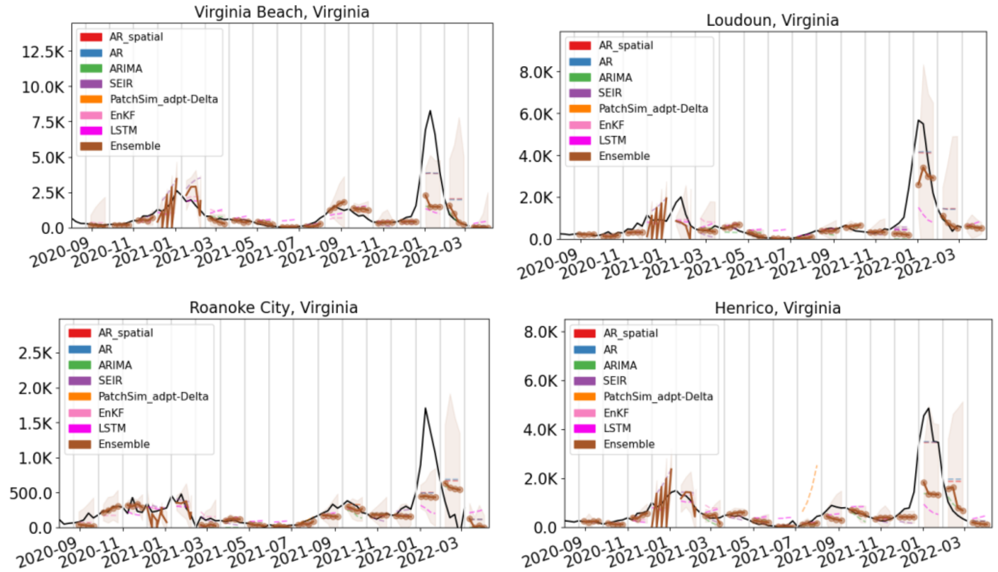
<u>Weekly forecasts </u>done at county level.

Models chosen because of their track record in disease forecasting and to increase diversity and robustness.

Ensemble forecast provides additional ‘surveillance’ for making scenario-based projections.

Also submitted to CDC Forecast Hub.





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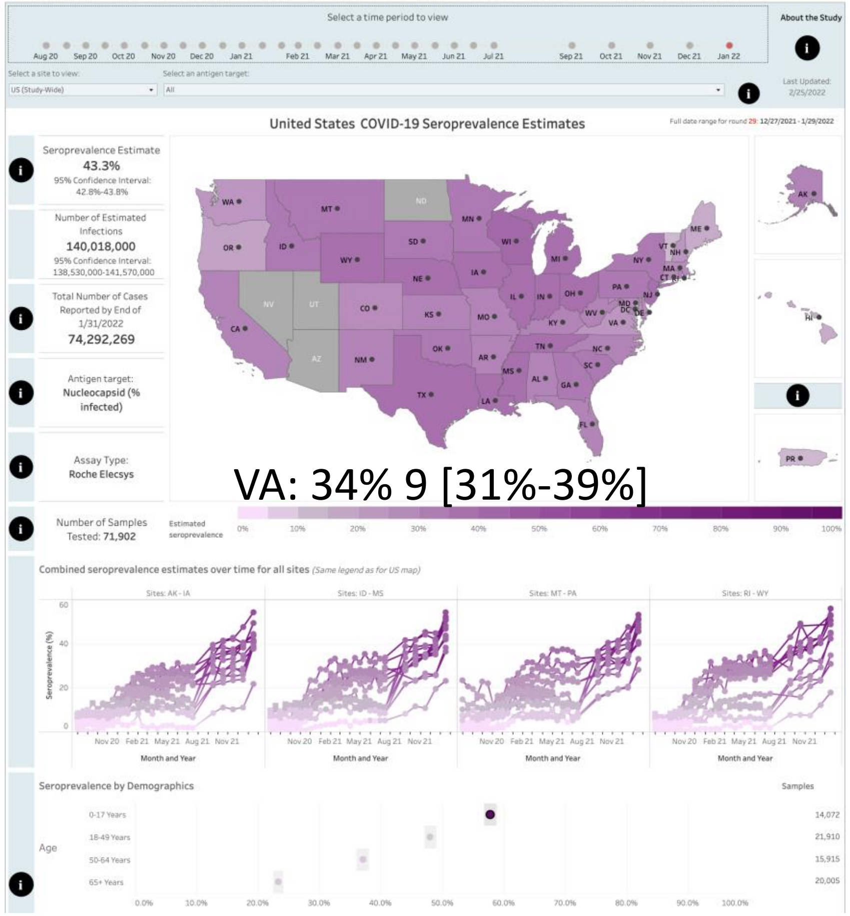
Seroprevalence updates to model design

Several seroprevalence studies provide better picture of how many actual infections have occurred

- CDC Nationwide Commercial Laboratory Seroprevalence Survey

These findings are equivalent to an ascertainment ratio of ~2x in the future, with bounds of (1.3x to 3x)

- Thus for 2x there are 2 total infections in the population for every confirmed case recently
- **Case ascertainment for Omicron infections are half of that for those with prior immunity**
- Uncertainty design has been shifted to these bounds (previously higher ascertainments as was consistent earlier in the pandemic were being used)



https://covid.cdc.gov/covid-data-tracker/#national-lab

Calibration Approach

- **Data:**
  - County level case counts by date of onset (from VDH)
  - Confirmed cases for model fitting
- **Calibration:** fit model to observed data and ensemble's forecast
  - Tune transmissibility across ranges of:
    - Duration of incubation (5-9 days), infectiousness (3-7 days)
    - Undocumented case rate (1x to 7x) guided by seroprevalence studies
    - Detection delay: exposure to confirmation (4-12 days)
  - Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak
- **Project:** future cases and outcomes generated using the collection of fit models run into the future
  - **Mean trend from last 7 days of observed cases and first week of ensemble's forecast used**
  - Outliers removed based on variances in the previous 3 weeks
  - 2 week interpolation to smooth transitions in rapidly changing trajectories
- **Outcomes**: Data driven by shift and ratio that has least error in last month of observations
  - Hospitalizations: 3 days from confirmation, 6.8% of cases hospitalized
  - Deaths: 11 days from confirmation, 1.45% of cases die

COVID-19 in Virginia: Summary

Dashboard Updated: 3/15/2022
Data entered by 5:00 PM the prior day.

Cases, Hospitalizations and Deaths

Total Cases*		Total Hospital Admissions**		Total Deaths	
1,656,187 (New Cases: 1,294)^		48,188		19,356	
Confirmed†	Probable†	Confirmed†	Probable†	Confirmed†	Probable†
1,182,581	473,606	45,326	2,862	16,075	3,281

* Includes both people with a positive test (Confirmed), and symptomatic with a known exposure to COVID-19 (Probable).
** Hospitalization of a case is captured at the time VDH performs case investigation. This underrepresents the total number of hospitalizations in Virginia.
^New cases represent the number of confirmed and probable cases reported to VDH in the past 24 hours.
† VDH adopted the updated CDC COVID-19 confirmed and probable surveillance case definitions on August 27, 2020. Found here: https://wwwn.cdc.gov/nndss/conditions/coronavirus-disease-2019-covid-19/case-definition/2020/08/05/
Source: Cases - Virginia Electronic Disease Surveillance System (VEDSS), data entered by 5:00 PM the prior day.

Outbreaks

Total Outbreaks*	Outbreak Associated Cases
7,194	120,393

* At least two (2) lab confirmed cases are required to classify an outbreak.

Testing (PCR Only)

Testing Encounters PCR Only*	Current 7-Day Positivity Rate PCR Only**
12,972,259	4.2%

* PCR" refers to "Reverse transcriptase polymerase chain reaction laboratory testing."
** Lab reports may not have been received yet. Percent positivity is not calculated for days with incomplete data.

Multisystem Inflammatory Syndrome in Children

Total Cases*	Total Deaths
163	1

*Cases defined by CDC HAN case definition: https://emergency.cdc.gov/han/2020/han00432.asp

Accessed 9:00am March 16, 2022
https://www.vdh.virginia.gov/coronavirus/

Scenarios – Transmission Conditions

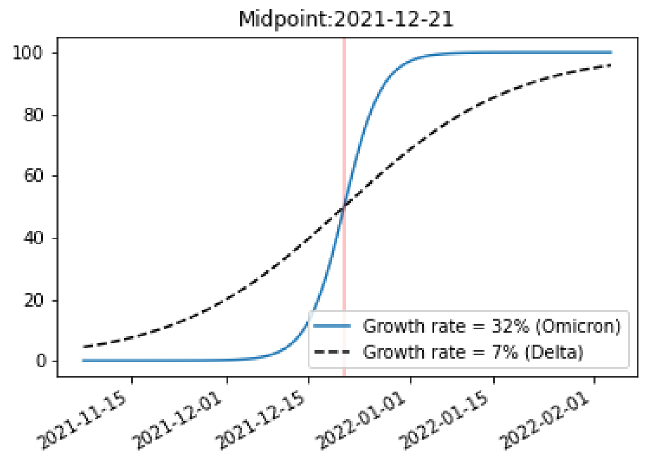
- Variety of factors continue to drive transmission rates
  - Seasonal impact of weather patterns, travel and gatherings, fatigue and premature relaxation of infection control practices
- **Waning Immunity**: Mean of 6 months to a year protection (rate of 0.0027) similar to Pfizer study
- **Projection Scenarios**:
  - **Adaptive:** Control remains as is currently experienced into the future with assumption that Omicron remains as the majority strain, and that infection with Omicron provides protection against Omicron infection in the future
  - **Adaptive-DecreasedControl:** Same as Adaptive, except transmission rates are driven up by 60% in the coming 2 weeks
  - **Adaptive-VariantBA2:** Same as Adaptive, but with gradual emergence of BA.2 subvariant with a 2x transmission advantage over existing Omicron subvariants

Scenarios – Omicron Description

Omicron shown ability to evade immunity and may be more transmissible

- **Transmissibility**: New evidence suggests that Omicron has **similar transmissibility** to Delta
- **Immune Evasion**: Strong evidence demonstrates that Omicron can cause infection in those with some immunity (natural and vaccine induced). Consensus estimate of **80% immune evasion** allows Omicron to infect 80% of individuals that would have otherwise been protected against Delta. Assume that recovery from Omicron provides protection to infection with Omicron similar pre-Omicron variants
- **Prevalence**: Proportion of cases caused by Omicron variant estimated from growth rates observed in other countries with similar levels of immunity (growth of 32%, doubling in ~3 days)
- **Severity:** Several reports suggest Omicron may not cause as severe disease as Delta, we use a 50% reduction in severity for hospitalizations and deaths
- Studies: South Africa, UK, Canada

Estimated Prevalence curve for US



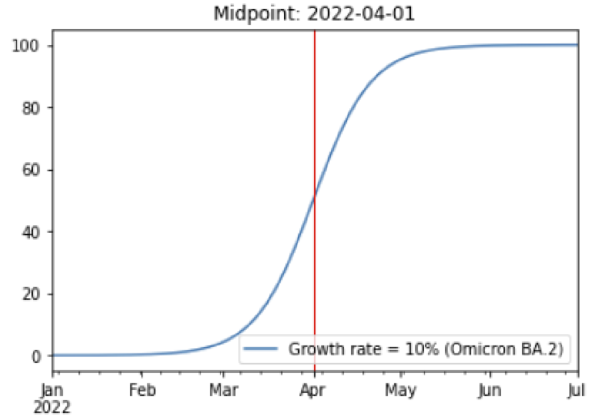
Predominance occurs before Jan 1, 2022

Scenarios – Omicron BA.2 Description

BA.2 shows signs of increased transmissibility

- **Transmissibility**: Analysis of household contacts in Denmark and the UK suggests a 40% to 3x increase in transmission. We assume a 2x boost for this scenario
- **Prevalence**: Detection in US has been widespread but limited; given growth observed elsewhere and US, and current estimated prevalence, this would lead to BA.2 prevalence of 50% in early April
- **Severity:** Assumed to be same as for other Omicron subvariants

Estimated BA2 prevalence projection



This projected prevalence is based on the increase experienced in Denmark the growth rate in VA may be markedly different

Table 3: Relative effect of Omicron VOC BA.2 vs. BA.1

	Susceptibility			Transmissibility		
	Unvaccinated	Fully vaccinated	Booster vaccinated	Unvaccinated	Fully vaccinated	Booster vaccinated
Omicron BA.2 households	2.19 (1.58-3.04)	2.45 (1.77-3.40)	2.99 (2.11-4.24)	2.62 (1.96-3.52)	0.60 (0.42-0.85)	0.62 (0.42-0.91)
Omicron BA.1 households	ref (.)	ref (.)	ref (.)	ref (.)	ref (.)	ref (.)
Number of observations	17,945	17,945	17,945	17,945	17,945	17,945
Number of households	8,541	8,541	8,541	8,541	8,541	8,541

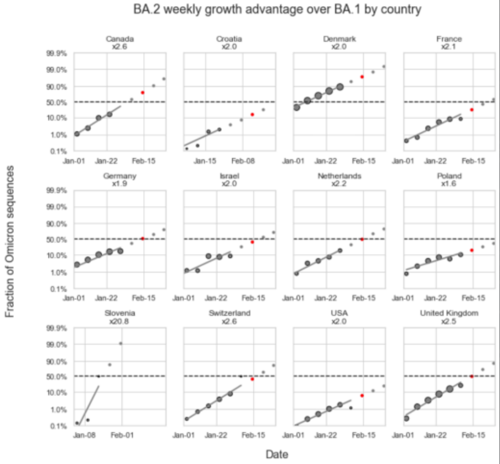
Notes: This table shows odds ratio estimates for the effect of living in a household infected with BA.2 relative to BA.1. Column 1 and 4 shows the relative transmission of BA.2, conditional on being unvac- cinated. Column 2 and 5 shows the relative transmission of BA.2, conditional on being fully vaccinated. Column 3 and 6 shows the relative transmission of BA.2, conditional on being booster vaccinated. Note, all estimates are from the same model, but with a different reference category across column 1-6. The estimates are adjusted for age and sex of the primary case, age and sex of the potential secondary case, size of the household, and primary case sample date. The estimates are furthermore adjusted for vacci- nation status of the potential secondary case and primary case interacted with the household subvariant. 95% confidence intervals are shown in parentheses. Standard errors are clustered on the household level. The odds ratio estimates for the full model are presented in Appendix Table 12, column I

Danish Household Study - MedArxiv

Table 4. Secondary attack rates for contacts of cases with confirmed sequenced VUI-22JAN-01 and all other Omicron (VOC-21NOV-01)
(Case test dates 1 January to 14 February 2022, variant data as of 7 March 2022 and contact tracing data as of 8 March 2022)

Variant	Setting	Number of exposing cases	Number of contacts	Adjusted* secondary attack rate (95% Confidence Interval)
VOC-21NOV-01	Household	178,069	369,011	10.7% (10.6%-10.8%)
VUI-22JAN-01	Household	20,072	41,621	13.6% (13.2%-14.0%)
VOC-21NOV-01	Non-household	30,325	74,343	4.2% (4.0%-4.3%)
VUI-22JAN-01	Non-household	3,565	8,763	5.3% (4.7%-5.8%)

UK HAS report shows 2ndary Attack rates ~30% higher in households and out of households.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1060337/Technical-Briefing-38-11March2022.pdf



Many countries Tracking a 2x Advantage for BA.2 vs. BA.1

Barak Raveh via Twitter

Projection Scenarios – Combined Conditions

Name	Txm Controls	Vax	Description
Adaptive	C	SQ	Likely trajectory based on conditions remaining similar to the current experience, includes immune escape due to Omicron
Adaptive-DecreaseControl	Decrease	SQ	Transmission rates in the next couple weeks are increased 60% and remain at that level demonstrate that increases in case rates remain possible despite the historically high rates, remaining vigilant has benefits
Adaptive-VariantBA2	C	SQ	Transmission rates for BA.2 infections are doubled. BA.2 prevalence rises over the course of next 8 weeks from not detected to ~95%

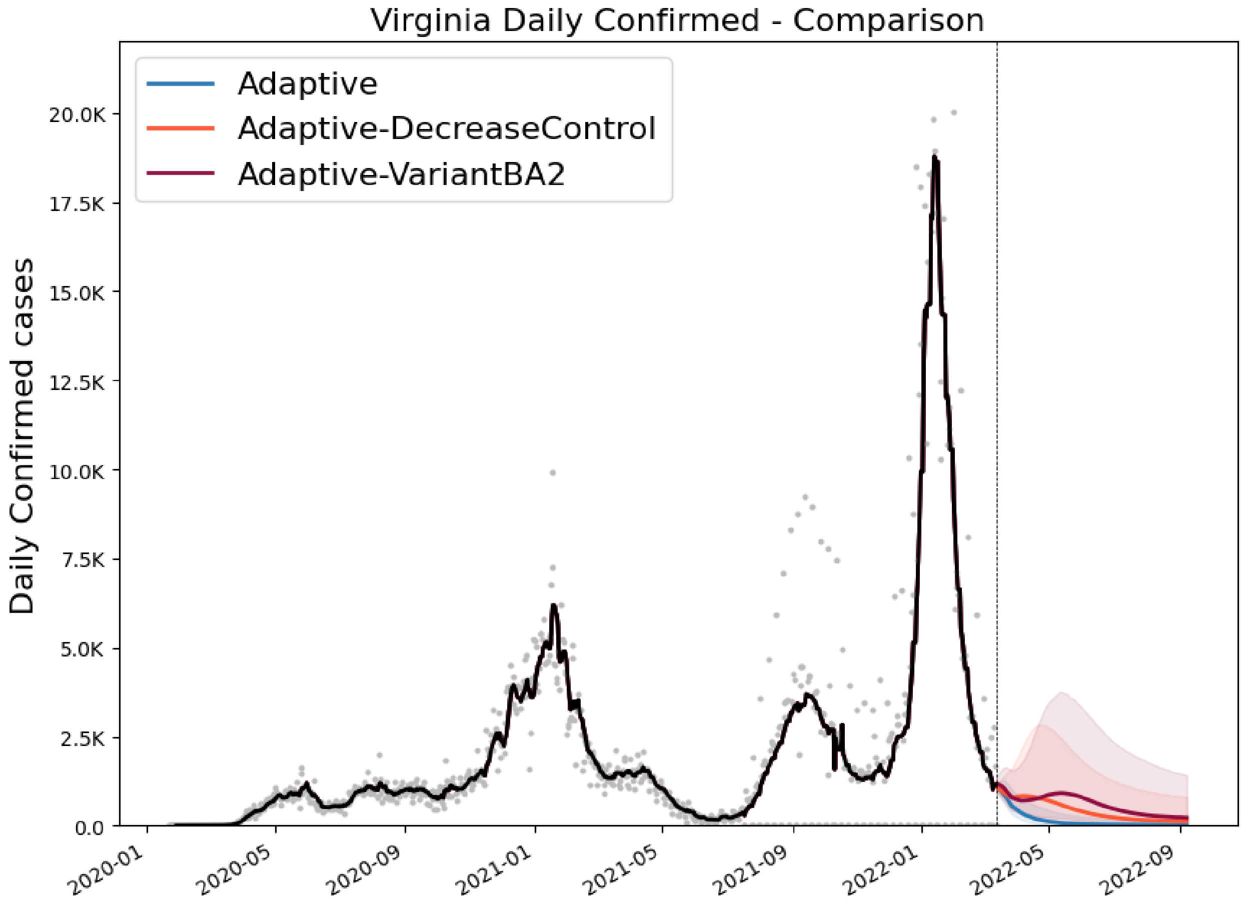
Transmission Controls:
C = Current levels persist into the future
Decrease = Transmission rates are boosted by 60% over next couple weeks and remain at that level
Spring = Transmission rates from mid-Jan 2021 through mid-March 2021 are coarsely replayed, representing a 60% reduction in transmission rate drivers, with Omicron remaining dominant

Vaccinations:
SQ = Status quo acceptance leads to low rates of vaccination through the summer
VO = Vaccination acceptance optimistically expands with increased rates through the summer

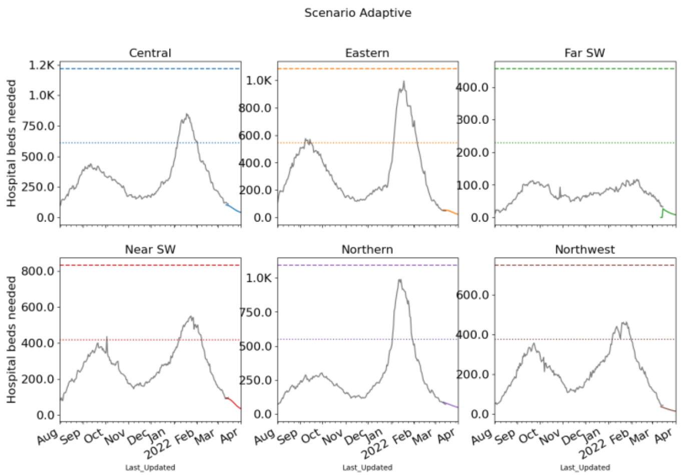
Model Results

Outcome Projections

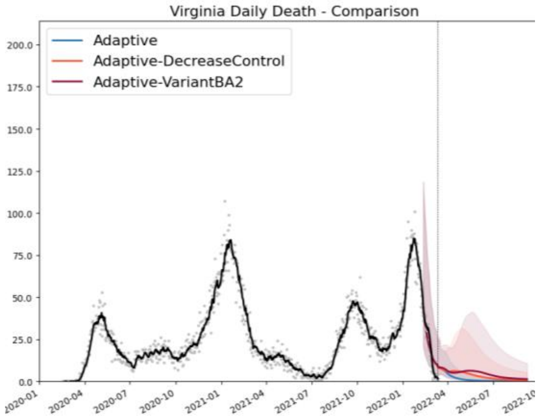
Confirmed cases



Estimated Hospital Occupancy

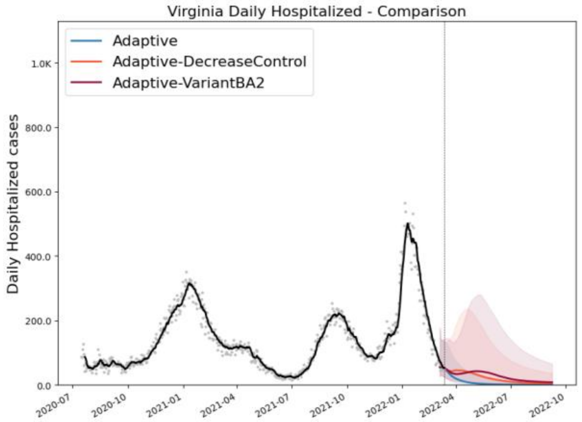


Daily Deaths



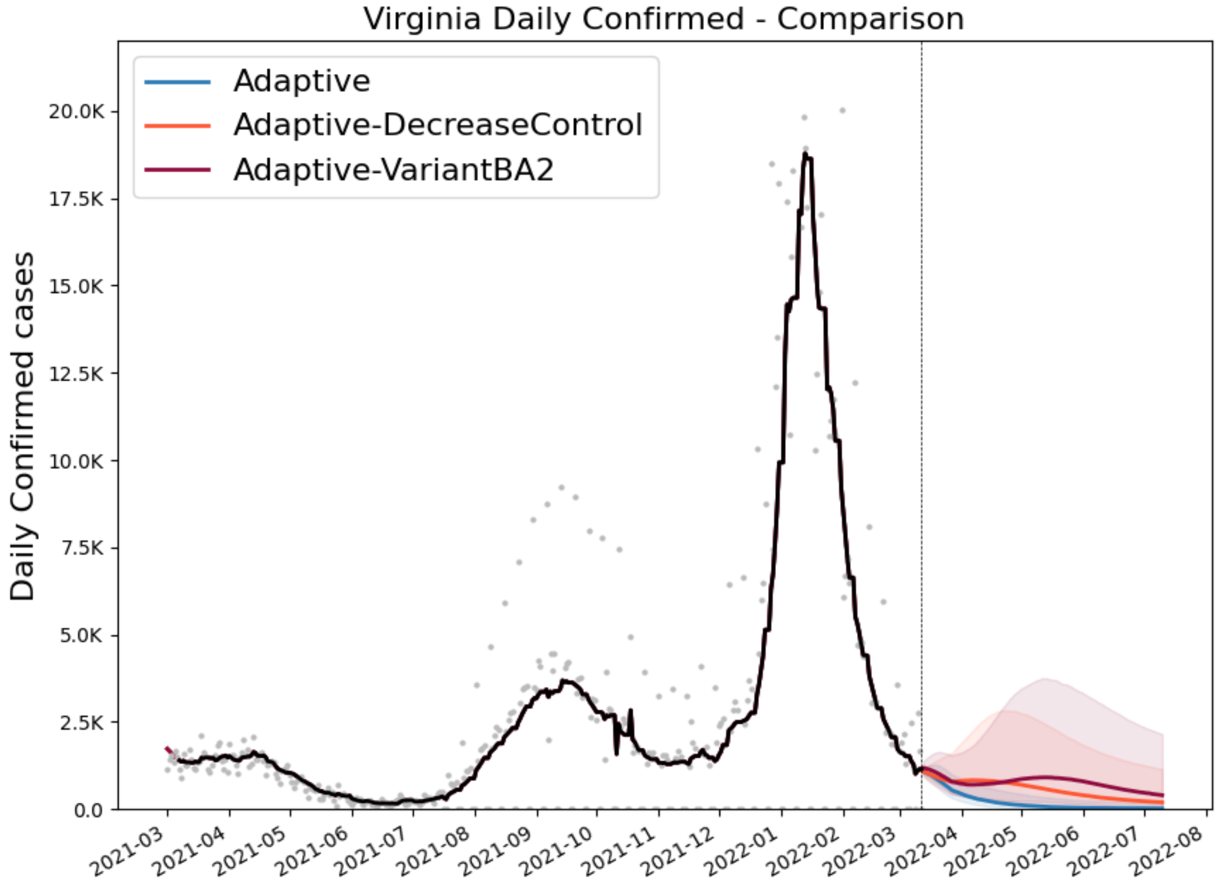
Death ground truth from VDH “Event Date” data, most recent dates are not complete

Daily Hospitalized

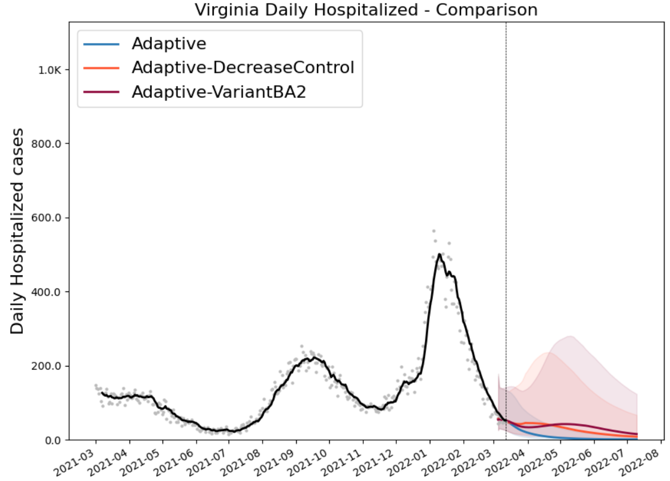


Outcome Projections – Closer Look

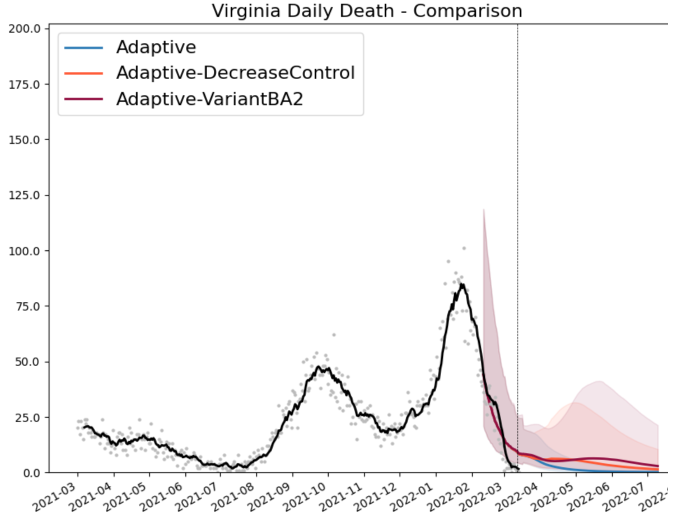
Confirmed cases



Daily Hospitalized



Daily Deaths



Death ground truth from VDH “Event Date” data, most recent dates are not complete

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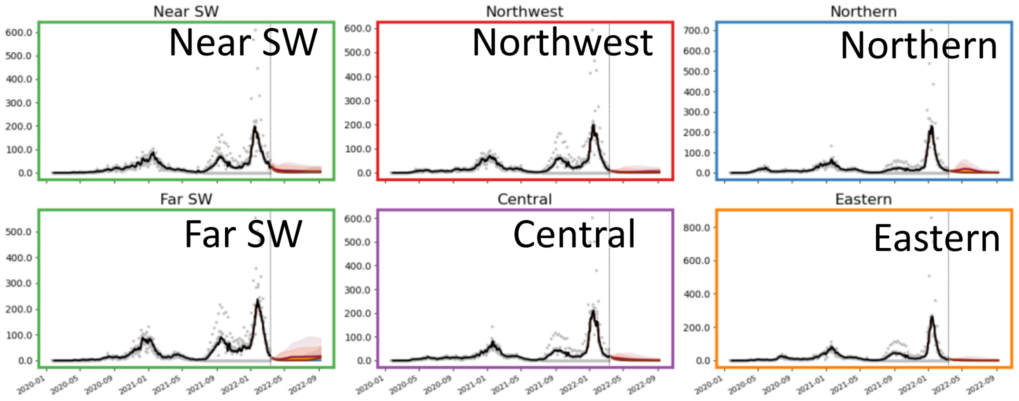
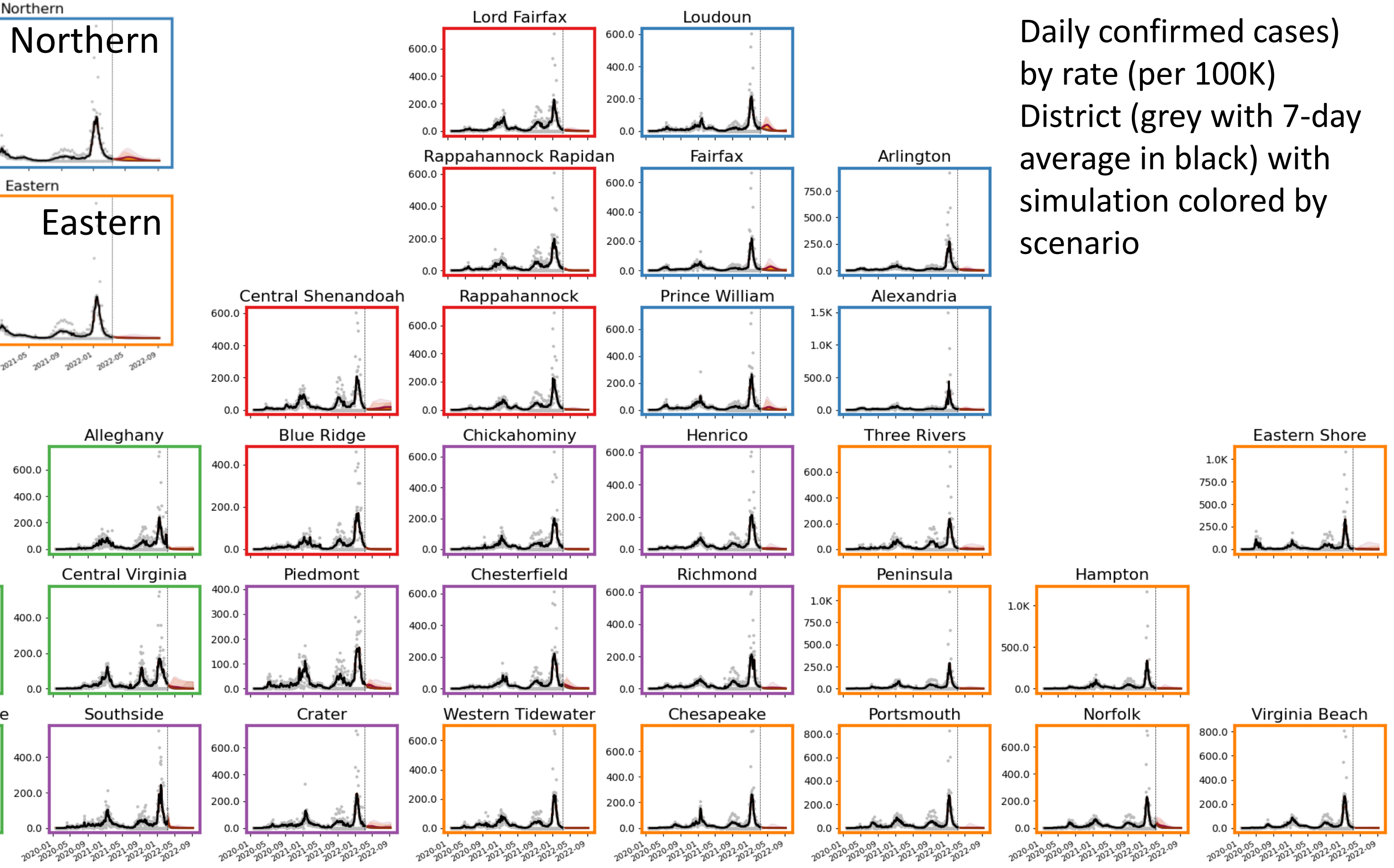
Detailed Projections: All Scenarios

Projections by Region



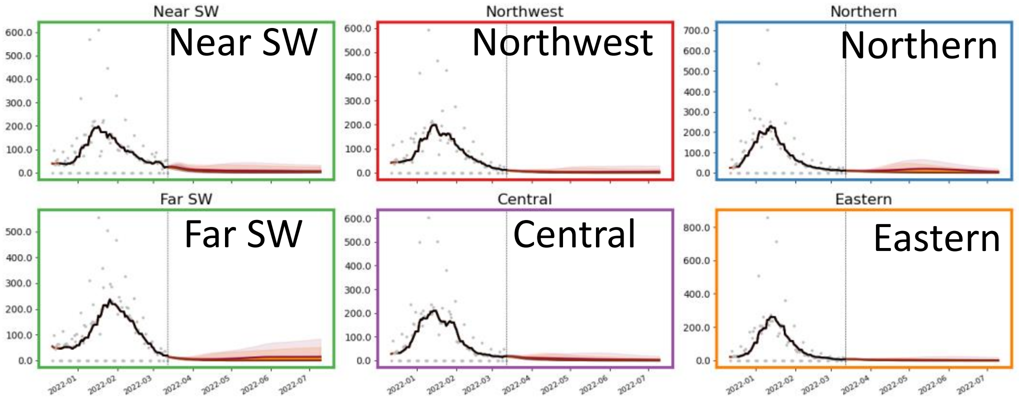
Projections by District



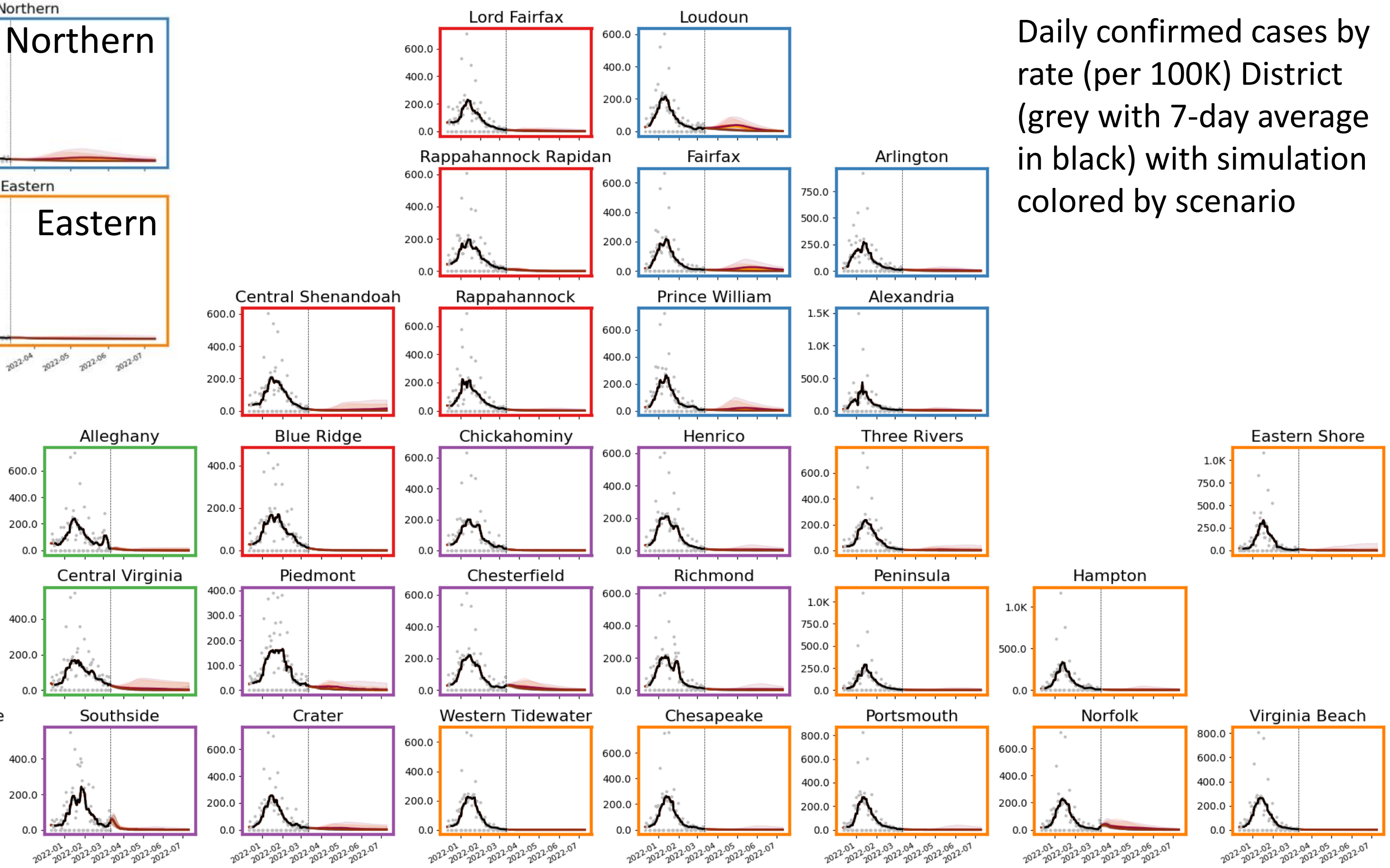
Daily confirmed cases) by rate (per 100K) District (grey with 7-day average in black) with simulation colored by scenario

Detailed Projections: All Scenarios - Closer Look

Projections by Region



Projections by District



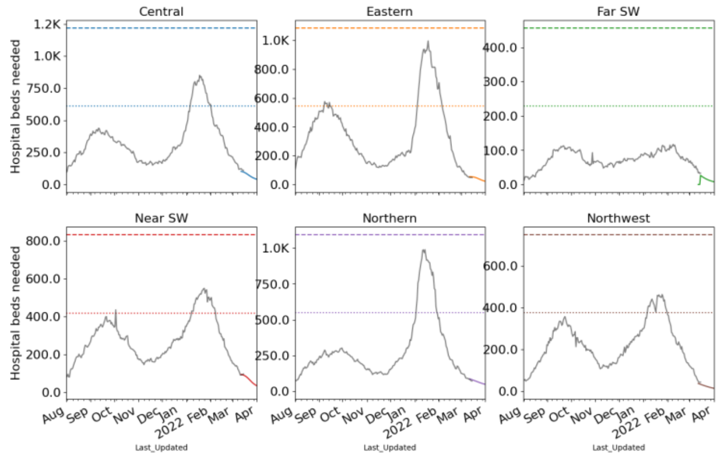
Daily confirmed cases by rate (per 100K) District (grey with 7-day average in black) with simulation colored by scenario

Hospital Demand and Bed Capacity by Region

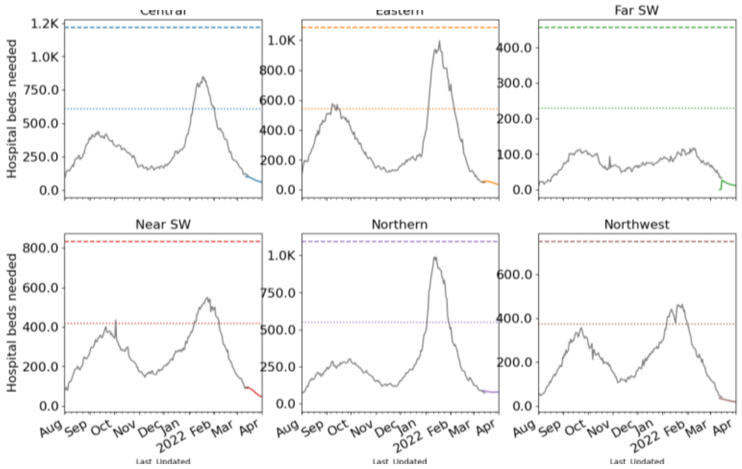
Capacities by Region

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds

Adaptive



Adaptive – Variant BA2



Length of Stay Estimates

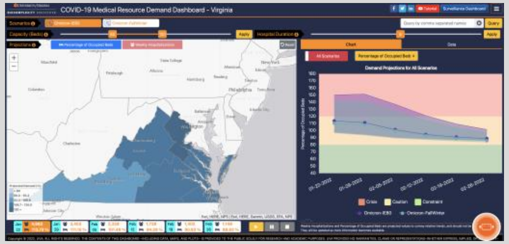
Central	8
Eastern	7
Far SW	10
Near SW	8
Northern	6
Northwestern	8

Length of Stay more variable with Omicron, occupancy projections may vary as a result, ad-hoc estimation performed per region

Estimated LOS stable with only the Far SW shifting to longer stays

Projections show continued declines and with expanded capacities and adjusted length of stay, no capacities exceeded

Interactive Dashboard with regional projections

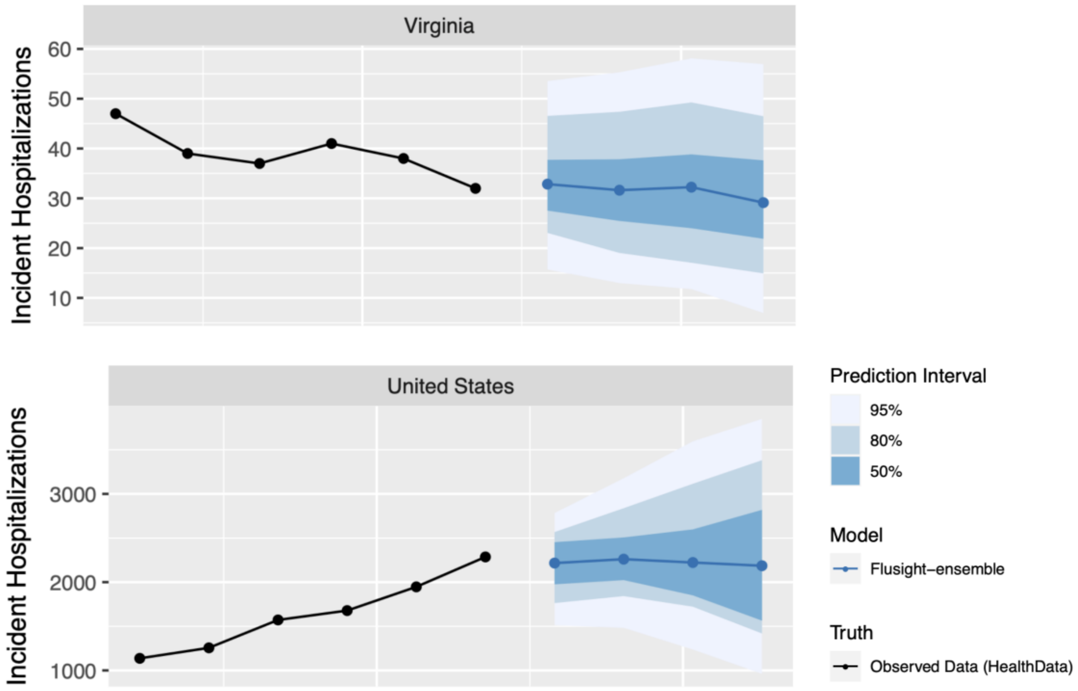


https://nssac.bii.virginia.edu/covid-19/vmrddash/

Current Influenza Hospitalization Forecast

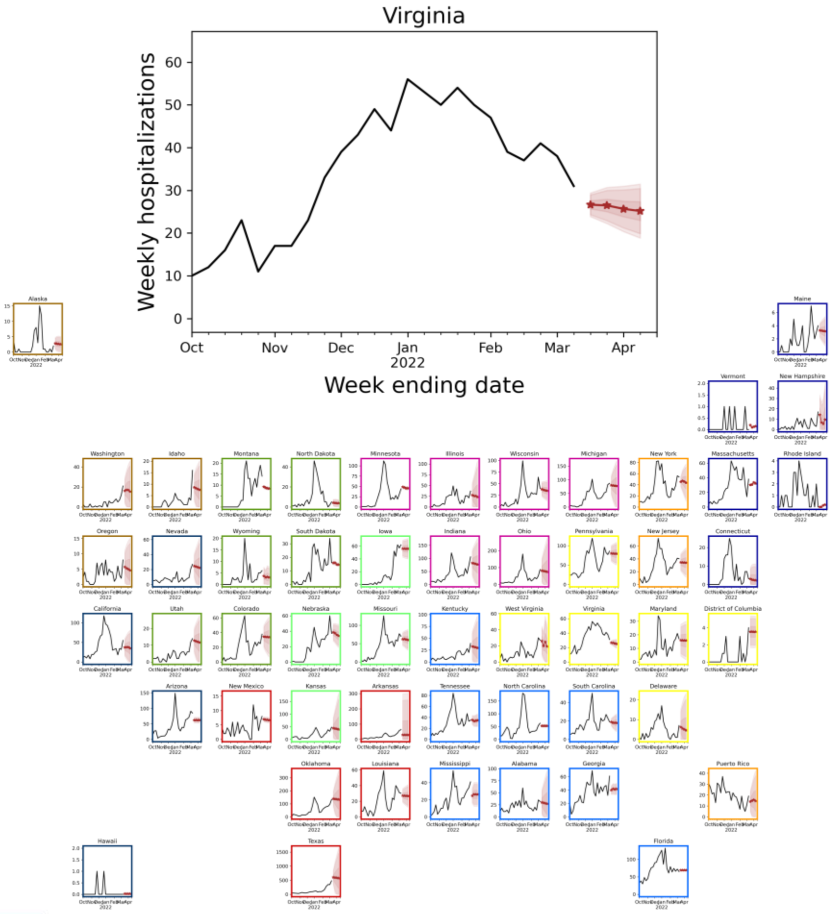
Statistical models for submitting to CDC FluSight forecasting challenge

- Hospitalizations nationwide are rising, VA still steady



CDC FluSight
Ensemble Forecasts
(Mar 14th)

Hospital Admissions for Influenza and Forecast for next 4 weeks (UVA ensemble)



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Key Takeaways

Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

- **Case rates and hospitalizations continue to decline, though rate of decline is slowing**
- VA 7-day mean daily case rate slowly decreased to 11/100K from 14/100K
  - US continues declines to 10/100K (from 13/100K)
- BA.2 subvariant of Omicron has resumed steady growth, though slower than previously observed in European countries many of which now have rebounding case rates
- Projections anticipate continued declines:
  - Future levels and resilience to new variants and reduced infection control measures depend on the strength of immunity gained through infection with Omicron and its durability against waning
- Model updates:
  - Further calibration of model parameters to match recent data on population immunity post-Omicron wave continue and will provide better long-term estimates of future disease dynamics

The situation continues to change. Models continue to be updated regularly.

Additional Analyses

Overview of relevant on-going studies

Other projects coordinated with CDC and VDH:

- **Scenario Modeling Hub:** Consortium of academic teams coordinated via MIDAS / CDC to that provides regular national projections based on timely scenarios
- **Genomic Surveillance:** Analyses of genomic sequencing data, VA surveillance data, and collaboration with VA DCLS to identify sample sizes needed to detect and track outbreaks driven by introduction of new variants etc.
- **Mobility Data driven Mobile Vaccine Clinic Site Selection:** Collaboration with VDH state and local, Stanford, and SafeGraph to leverage anonymized cell data to help identify

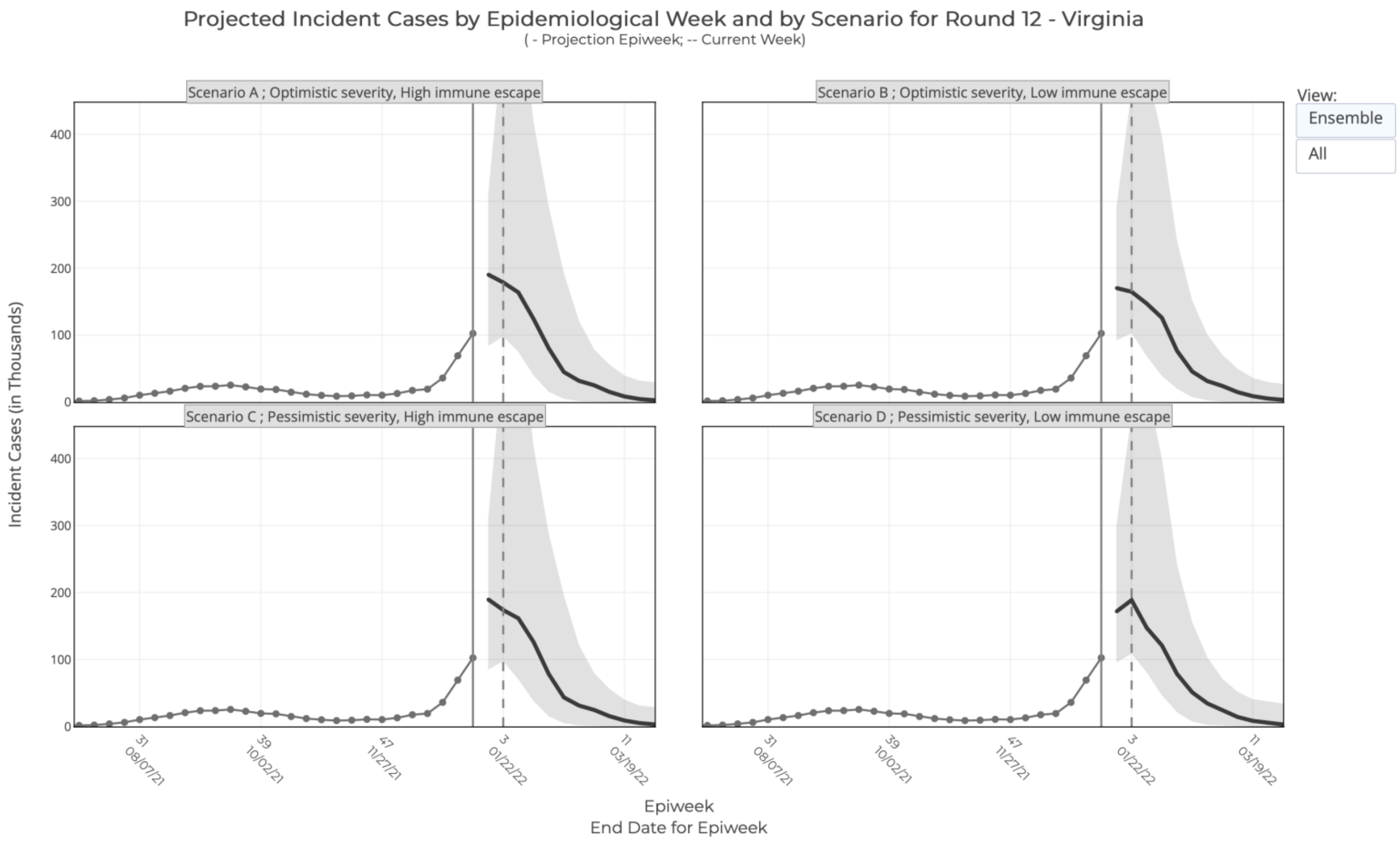
COVID-19 Scenario Modeling Hub

Collaboration of multiple academic teams to provide national and state-by-state level projections for 4 aligned scenarios that vary vaccine rates (high – low) and impact of the Delta variant (high and low)

- Round 12 recently released to assist in federal response to Omicron wave
- Only national consortium tracking Omicron wave well
- Rounds 4-11 now available

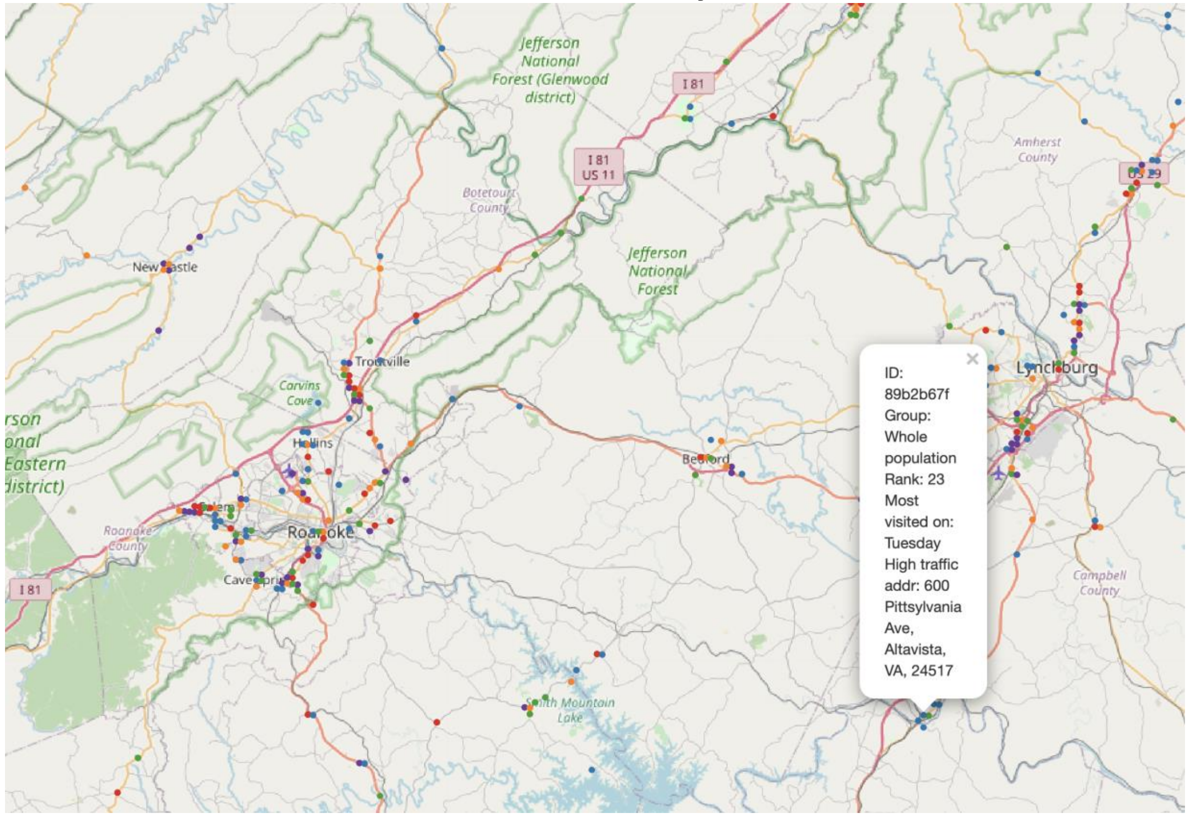
Round 4 Results were published May 5th, 2021 in MMWR

https://covid19scenariomodelinghub.org/viz.html



Data Recommended Mobile Vax Clinic Sites

Detailed and Timely Locations



Data Delivered and Disseminated to Locals

Provides a list of areas most visited by a given demographic group based on SafeGraph mobility data that links visits to specific sites and the home Census Block Group of the anonymized visitors

Demographic Groups: Black, Lantinx, Young Adults (20-40), Unvaccinated, and Whole Population

Data Included: Rank, Weight, most visited Day of Week, Highly Visited Address, and Lat-Long of area

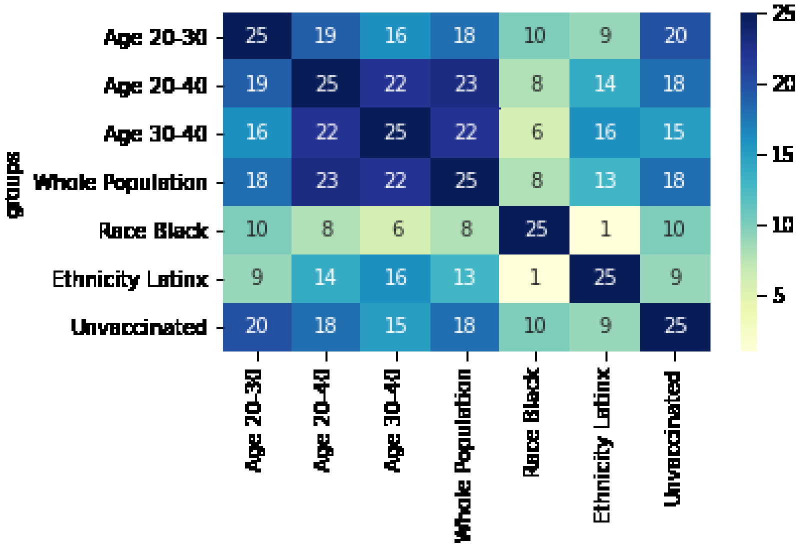
Goal: Provide frequently visited locations based on populations and vaccination levels one desires to reach

Example: List of location in the Southside frequented by 20-40 year olds

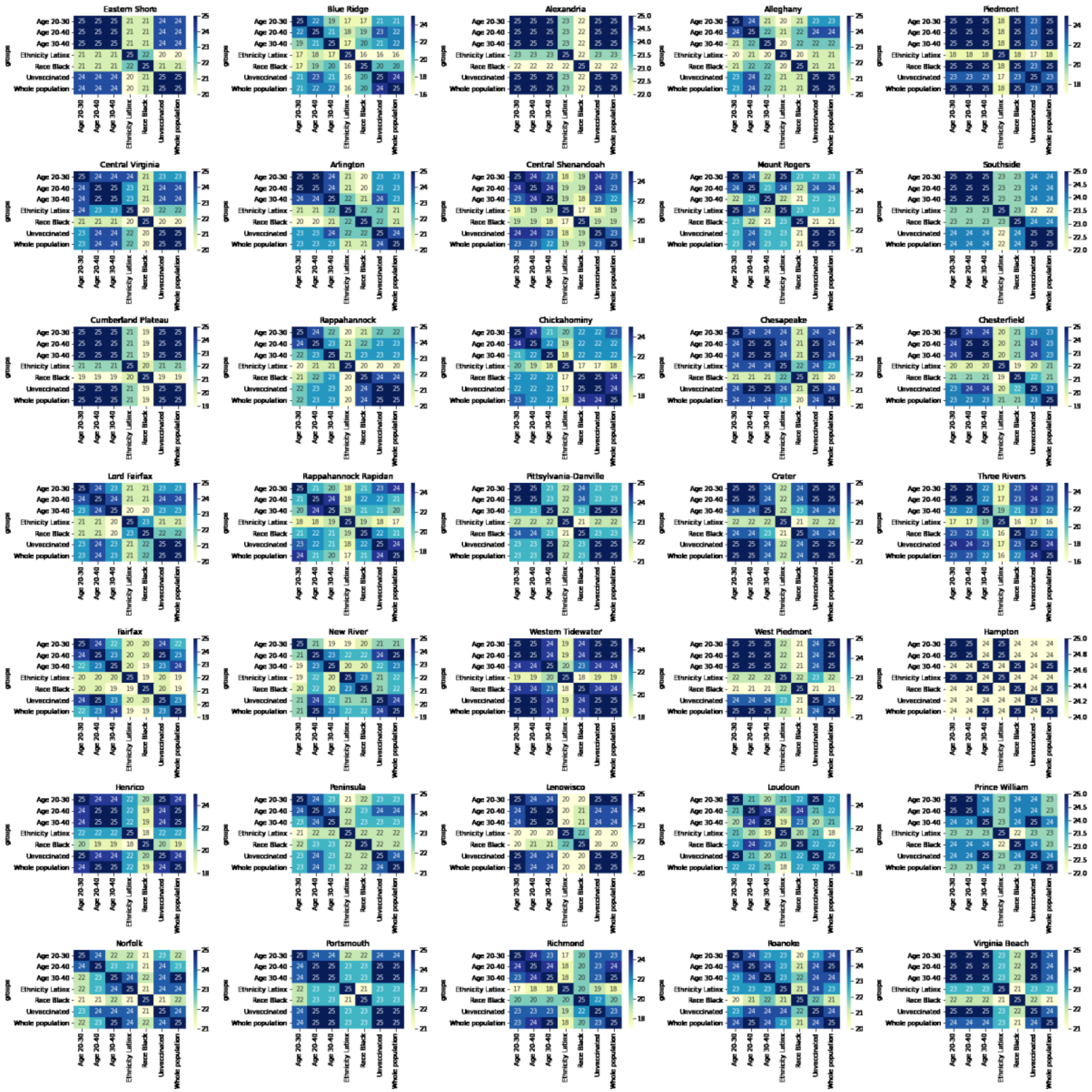
Data Recommended Mobile Vax Clinic Sites

Overlap of locations between groups

State Level



Within VDH Health Districts



Different groups visit different areas

- Least overlap between Black and Latinx
- Overlap in ages highest, but drops with large gap
- Districts have different overlap patterns

References

Venkatramanan, S., et al. "Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints.” *PLoS Computational Biology* 15.9 (2019): e1007111.

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NSSAC. PatchSim: Code for simulating the metapopulation SEIR model. https://github.com/NSSAC/PatchSim

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Biocomplexity Institute. COVID-19 Surveillance Dashboard. https://nssac.bii.virginia.edu/covid-19/dashboard/

Google. COVID-19 community mobility reports. https://www.google.com/covid19/mobility/

Biocomplexity page for data and other resources related to COVID-19: https://covid19.biocomplexity.virginia.edu/

Questions?

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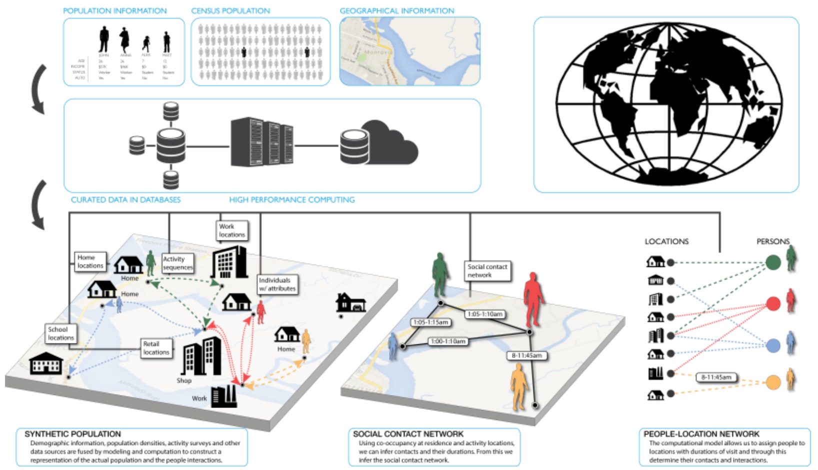
Supplemental Slides

Agent-based Model (ABM)

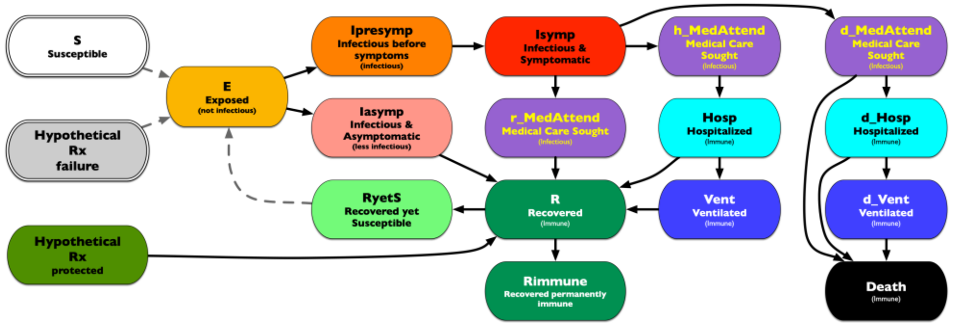
EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing



Synthetic Population

- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations



Detailed Disease Course of COVID-19

- Literature based probabilities of outcomes with appropriate delays
- Varying levels of infectiousness
- Hypothetical treatments for future developments